CATALOGUE OF

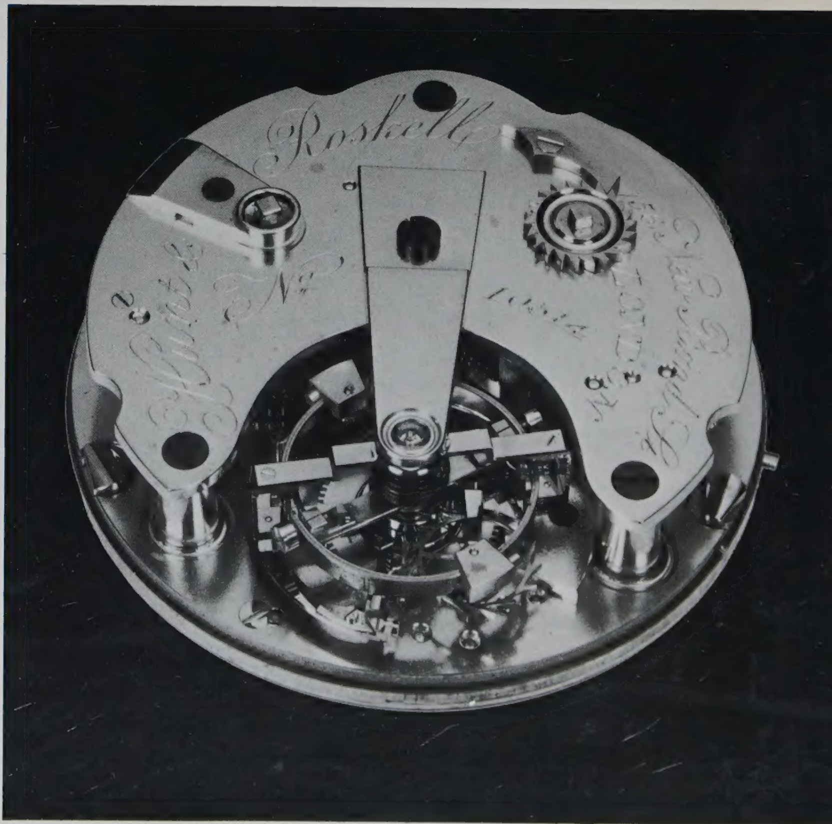
Watches

IN THE

BRITISH MUSEUM

VI
Pocket Chronometers, Marine Chronometers and Other Portable Precision Timekeepers

ANTHONY G. RANDALL
AND RICHARD GOOD



This is the sixth of six catalogues (but the second to be published), each dealing with one major aspect of the British Museum's extraordinarily rich and diverse collection of over 2,000 watches and watch movements ranging from the Renaissance to the modern. Each volume covers particular innovations in mechanical construction and the various refinements associated with them, thus providing a six-part survey of horological developments in watchmaking over the past 400 years.

Volume VI is devoted to precision watches, chronometer escapement timepieces and marine chronometers from the eighteenth to the early twentieth century. (For the purposes of this volume it is taken that a precision timekeeper must possess some form of temperature compensation, and that it was made with the express purpose of keeping time to the highest standard of its day.)

The catalogue includes 193 mechanisms, grouped according to the four principal ways in which makers tackled the problem of accurate timekeeping (adding devices to compensate for changes in temperature, improving escapements, reducing variations in motive power, and counteracting the effects of changes in position). Every timekeeper is illustrated, with an average of four views. Marine chronometers are also included, despite the fact that they are considered to be neither watches nor clocks, for two reasons. First, many have a detent escapement, all examples of which are included in the catalogue; and secondly, being portable, all marine chronometers are balance controlled.

In his Historical Introduction, Richard Good discusses the beginnings of accurate timekeeping, navigation at sea and the importance of being able to determine longitude, and the work of the great makers who invented and developed precision timekeepers. In addition, every section of the catalogue is prefaced by a technical introduction with explanatory line drawings and diagrams.

The volume is completed by an appendix, technical data, a concordance, a glossary and an index, making this an invaluable reference work as well as an important addition to this major catalogue series.

With 176 plates and 25 line drawings

Jacket Tourbillon by Hunt and Roskell (cat. no. 177), with mechanism shown separately

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CATALOGUE OF WATCHES IN THE BRITISH MUSEUM

VI

Pocket Chronometers, Marine Chronometers and Other Portable Precision Timekeepers

by

ANTHONY G. RANDALL

revised by

RICHARD GOOD

PUBLISHED FOR THE TRUSTEES OF THE BRITISH MUSEUM
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FOREWORD

Volume VI of the *Catalogue of Watches in the British Museum* is devoted not only to precision watches and chronometer escapement timepieces but also to marine chronometers. The latter are included for two reasons: they are portable and thus are balance controlled; secondly, many of them have the detent escapement, and all the examples of this type of escapement, whether or not the mechanism as a whole can be considered a precision mechanism, have been included in this volume.

In fact this is the second volume of the *Catalogue* to be published, although the sixth in our order of classification of the watch collections as it was set out in the preface to Volume I (published in 1987). With such infinitely complex and delicate mechanisms, the value of this catalogue is more than usually high. Not only does it make accessible through drawings and technical descriptions the minutiae of these mechanisms, but in doing so it ensures that too much future handling and dismantling of these precious pieces is avoided. The volume has been long in the writing but will, I hope, more than justify the devotion and skill which has gone into its production.

Some words are in order about the genesis and history of this volume. Anthony Randall catalogued numbers 1–185. His meticulous descriptions covered the technical aspects of the mechanisms and other background material. These descriptions were subsequently revised by my colleague, Richard Good, formerly Superintendent of our Horological Students' Room; he checked the technical data and added certain bibliographical and provenance details. Another colleague, David Thompson, has added information on the watch cases. Thus in its final form the catalogue section is 'Randall revised by Good'.

The Historical and Technical Introductions are substantially the work of Richard Good, and he also compiled the Appendix, Glossary, Bibliography and Index.

Hugh Tait, the author of Volume I of the *Catalogue*, was responsible for the scope and layout of this volume as its original editor; to him our thanks are due. When the *Catalogue* was first in preparation, Beresford Hutchinson was involved as Superintendent of the Horological Students' Room with the preparation of Mr Randall's catalogue entries. Commander Derek Howse was of particular help over the history of the chronometers which had previously passed through Greenwich; he supplied a complete run of the Greenwich trial results, thus making it possible to gauge the effectiveness of the various forms of compensation balance. Thanks are also due to Rodney Law, who was kind enough to read the Historical Introduction and who made some valuable contributions.

The photography was carried out mainly under the supervision of Anthony Randall and Elliott Nixon by the British Museum's Photographic Department; especial thanks are due to John Heffron and Alan Hills, who undertook the major photographic work. Elliott Nixon was also responsible for preparing dimensioned sketches, which were then checked by David Penny, who used them to prepare the line drawings. Although his drawings are models of clarity, Mr Penny has asked that it be made clear in this foreword that his work on the volume dates from some ten years ago.

The authors also wish to thank the following, who have helped in many and various ways with the writing of this book – colleagues in the Research Laboratory of the British Museum and members of the staff of the Science Museum, Charles Allix, Dana Blackwell, George Daniels, Jeremy Evans, Cedric Jagger, John Leopold, Vaudrey Mercer, Alan Smith and Tommy White.

NEIL STRATFORD
Keeper, Medieval and Later Antiquities
April 1989

HISTORICAL INTRODUCTION

THE BEGINNING OF ACCURATE TIMEKEEPING

At the beginning of the eighteenth century the portable timekeeper was still a poor thing when judged solely in terms of its ability to keep accurate time. In the previous century there had been some improvements in production techniques, but the major step forward followed the invention of the balance spring by Dr Robert Hooke or Christian Huygens in about 1675.[1] This spring, when used in conjunction with a balance, provided a portable oscillator with isochronous properties, which improved the accuracy of timekeeping dramatically. There were still, however, many problems to be overcome and it was not until the eighteenth century that most of the necessary improvements were made. But why did the great clock and watchmakers of the eighteenth century feel the need to strive for greater and greater accuracy?

Until late in the nineteenth century the time kept by ordinary people was mostly local time as would be shown by a sundial in their area. It mattered little that from east to west the rotation of the earth caused local time to be different from place to place. To give an example: at noon in London local solar time in Plymouth would be 11.44 a.m. and in Norwich it would be 12.05 p.m. This variation across the country was not important to the majority of people, whose lives were more influenced by the available hours of daylight and did not affect communications, which were still relatively slow and restricted. On the other hand, time measurement was of great importance to surveyors, astronomers, scientists and travellers. Above all it was fundamental to the maritime navigator whose longitude at sea could most easily be found by comparing times in different places and it was the navigators need for a portable time-measuring instrument capable of considerable accuracy which, probably more than anything, stimulated the major technical advances in accurate timekeeping.

NAVIGATION AT SEA

At the beginning of the fifteenth century most trade between Europe and Asia was conducted either overland or through the Black and Mediterranean Seas and was almost entirely in the hands of the Italian states of Genoa and Venice. Portugal was denied this trade and so was forced to look to naval expansion southward. Prince Henry, 'The Navigator', gave impetus to this movement. Eventually the Portuguese found a seaway to the East by going around the Cape of Good Hope and Vasco da Gama reached India in 1498.

To the navigator at sea it was of vital importance to know the position of his ship in terms of latitude and longitude particularly when out of sight of known land.[2] In addition to the ever-present danger of shipwreck the amount of food and, more especially, fresh water, which could be carried on the long and arduous voyages was limited and errors in establishing position often resulted in the loss of ships, cargoes and crews. Finding latitude was a fairly straightforward matter of making observations of the sun or stars. But finding longitude with any degree of precision without the aid of an accurate timekeeper, was a very complicated process and was virtually impossible for navigators at that time.

Even before the birth of Christ, Hipparchos (190–120 BC) had advocated a method of finding longitude using eclipses of the moon, since such events take place at the same time regardless of the position of the observer. Thus the difference in local time between two observers would indicate their difference in longitude. Unfortunately an eclipse cannot occur unless the sun is below the horizon, thus making it impossible to use a sundial to establish local time. There is no record that this difficulty was ever overcome. The first fundamental development in the finding of longitude occurred in 1514 when Johann Werner described a lunar distance method (see Bibliography).

METHODS OF FINDING LONGITUDE

The Lunar Distance Method

During the course of a month the moon appears to move one complete revolution from west to east when compared with the stars that form its background. This relative movement, approximately $\frac{1}{2}°$ per hour (equal to the moon's diameter), enables the moon to be used as a gigantic celestial clock, the moon being the hand and the stars in the Zodiac the numerals on the dial. Using this phenomenon gave the first hope of finding longitude at sea.

Before Werner's suggestion could be put to effective use, however, it was necessary to know the precise positions of the stars, to predict for a number of years ahead the moon's position relative to these stars and to have an instrument capable of making the observations to the necessary accuracy. It was to be 250 years before these needs were satisfied and thus for Werner's suggestion to become practical.

The Use of Timekeepers

Meanwhile it was plain that Hipparchos' suggestion would be equally applicable if it were possible to carry around the time as at some fixed position on the earth's surface; knowing the time locally would then enable the observer to determine his longitude relative to this fixed position. The accuracy with which longitude could then be established would depend entirely on the accuracy of the timekeeper.[3]

However, if a timepiece were taken from London to Plymouth, a relatively short journey taking approximately four days by horse, an error of four minutes in the four days would produce an error of 1° of longitude, which at the latitude concerned would amount to approximately fifty miles. Such errors at sea could obviously have disastrous consequences.

The first author known to have proposed a timekeeper for finding longitude was Gemma Frisius in his *De Principiis Astronomiae Cosmographicae*, published in Louvain in 1530. It was, however, to be another 200 years before a timepiece could be produced which was sufficiently accurate and reliable in adverse and varying conditions to determine longitude with any degree of precision.

All the major maritime nations were aware of the importance of finding a reliable method of determining longitude and to encourage this work in 1567 Philip II offered a reward of 6,000 ducats as perpetual income for life and 1,000 ducats towards expenses. The whole prize was never won but considerable sums were spent in encouraging inventors. At about the same time the States General of Holland offered 30,000 florins and Portugal and Venice also offered large awards.[4] However, the largest award, and also apparently the only one ever paid in full, was that offered by the British government.

A committee was set up by Charles II to investigate the (false) claims of the Sieur de St Pierre, who declared that he had successfully used the method of lunar distance to establish longitude. As an indirect result of this the Royal Observatory at Greenwich was created in 1676 for 'rectifying the tables of motions of the heavens and the places of the fixed stars, so as to find out the so-much-desired longitude of places for perfecting the art of navigation.'[5] John Flamsteed (1646–1719) was the first Astronomer Royal.

Eclipses of Jupiter's Satellites

The existence of four bright moons revolving around Jupiter was disclosed by the telescope after its invention in the first few years of the seventeenth century. As with our own moon, these appear and disappear as they emerge from and pass into the planet's shadow. Galileo Galilei (1564–1642) pointed out that if the eclipses could be accurately timed and predicted they could be used to find longitude in exactly the same way as the behaviour of the Earth's own moon. In fact they could give superior results because the duration of observation is shorter and the eclipses occur once or twice each night.

In 1616 Galileo applied for the Spanish prize, basing his claims on the use of Jupiter's moons. However the Spaniards were not impressed and, much later, in 1636 Galileo tried Holland, saying that he had spent twenty-four years perfecting the tables for predicting the eclipses of Jupiter's moons. The States General were interested but because of Galileo's troubles with the authorities at the time,[6] negotiations were very difficult and in the event Galileo died before anything could be settled.

Galileo's method was, however, impracticable at sea, because of the difficulties involved in making the necessary observations, but it was to be used extensively on land.

RESOLVING THE PROBLEMS OF LONGITUDE AND THE DEVELOPMENT OF PRECISION TIMEKEEPING

The Act of Queen Anne

In 1707 a major disaster occurred at sea. Four ships of Admiral Sir Cloudesley Shovel's fleet were lost on the shores of the Scilly Isles, as they were returning from Gibraltar. The flagship was lost and the Admiral and nearly two thousand men perished.

Although not entirely due to difficulties in determining longitude, this was held to be an important factor and in 1714, on the advice of Sir Isaac Newton, the British government offered[7] under the Act of Queen Anne the following scale of rewards for the invention of a practical method of determining longitude:

£10,000 for any method capable of determining a ship's longitude to 1°
£15,000 if it was determined to within 40′
£20,000 if it was determined to $\frac{1}{2}$°
(£20,000 then is probably equivalent to £1,000,000 today)

The practical test was to be a voyage from the British Isles to a port in the West Indies without erring in longitude by more than the specified amount. This voyage would last about six weeks which meant that if a timekeeper was to be used there must be no more than an accrued error of two minutes – an average of three seconds a day! When one realises that the average watch of the time had errors of minutes a day, it is evident that something radical had to be done if a portable timekeeper was to be able to satisfy the requirements. The prize was eventually won by an Englishman, John Harrison.

The Development of the Chronometer in England

John Harrison (1693–1776)

John Harrison was born at Foulby in the parish of Wragby, Yorkshire, in 1693. His father was a carpenter and joiner in the service of Sir Rowland Winn of Nostell Priory and John was the eldest of a large family. He was trained in his father's trade but even as a child showed a fondness for mechanical things. When he was seven years old his father moved to Barrow-on-Humber where his employer had another estate and John subsequently turned his attention to the repair and improvement of clocks.

By 1713 he had built his first long-case clock, now preserved in the Collection of the Worshipful Company of Clockmakers. It was similar in construction to other clocks of the time except that it had, apart from the brass escape wheel, wheels of wood.

Soon after this he began to make improvements and by 1726 he and his brother James had made two clocks that kept time to a second a week – an astonishing degree of accuracy.

The two clocks had radically new features, including the use of a self-lubricating wood, *lignum vitae*, a compensation pendulum[8] known to this day as the Harrison Gridiron Pendulum and a new escapement that could run without lubrication, the 'grasshopper'.[9]

By 1730 John Harrison's long-case clocks were keeping time to a second a week, but fixed timekeepers have definite advantages over portable timekeepers. A static timekeeper can be weight-driven, which gives it an almost constant power supply. The portable timekeeper, however, is almost invariably driven by a mainspring whose power varies not only as it unwinds but also in the long term due to fatigue. Obviously, too, by definition, the portable timekeeper cannot be kept in one position. In the eighteenth century both fixed and portable timekeepers were equally subject to changes in temperature, pressure and humidity, although even here the portable timepiece could easily be subjected to more rapid and violent changes.

Since portable timekeepers in general needed to be small, they were also more readily susceptible to trouble causes by deterioration of the oil at the working surfaces. Harrison had a deep-seated objection to the use of oil, which was not surprising since the oils then available were of an inferior quality.[10]

In addition the oscillating system in the portable timekeeper has to be a balance and spring and this is subject to various influences which interfere with its isochronous properties.

The story of portable precision timekeepers is the record of the struggles of horologists to eliminate those influences, or when this was impossible to compensate for their effects, and begins in England in about 1730 when Harrison visited London. He went to London to learn more about the enormous sum being offered by Parliament for a solution to the longitude problem; one approach, and obviously the one that interested Harrison, lay in his now chosen field of precision timekeeping. He was introduced to the Astronomer Royal, Edmund Halley (1656–1741/2), who was Flamsteed's successor and a Commissioner for Longitude, and also to George Graham (1673–1751), the most influential clockmaker of the day. Graham had for a time been Thomas Tompion's partner and was himself responsible for two great advances in precision timekeeping: the invention of the mercurial temperature-compensated pendulum and the type of dead beat escapement that bears his name.

Graham recognised Harrison's genius and lent him money to help him to make his first sea-clock. He also persuaded both the East India Company and Charles Stanhope[11] to grant sums of money for the same purpose.

Thus encouraged, Harrison produced his first machine, which he called a sea-clock. A huge mechanism three feet high, now known as H1, it was finished in 1735. Not being satisfied with its performance he went on to build two more large machines, H2 and H3, the latter not finished until 1760. These machines ran without oil. In 1755, however, Harrison had told the Commissioners that he was making two watches. He explained that one was 'such good size as may be worn in the pocket, the other bigger ... having good reason to think from one already executed to his direction ... that such small machines may be ... of great service with respect to the longitude ... and may be purchased at a much cheaper rate than his superior machines.'[12] The Board examined the mechanical drawings of these watches, and after personal discussions with Harrison, they awarded him £500 '...to adjust his machine, and to bring the said two watches into as great perfection as possible'.

From this extract of the Board minutes, it is clear that Harrison had already had a watch made under his supervision, and that as a result of its successful performance, he had begun work on two others, one of pocket size and the other considerably larger.

The Astronomer Royal at this time, Nevil Maskelyne, in his 'Explanation' to the first *Nautical Almanac* pointed out the reasons why tabulations were given in apparent solar time rather than in mean solar time. He went on to say, however:

> But if Watches made upon Mr John Harrison's or other equivalent Principles should be brought into Use at Sea, the apparent Time deduced from an Altitude of the Sun must be corrected by the Equation of Time, and the Mean Time found compared with that shewn by the Watch, the Difference will be the Longitude in Time from the Meridian by which the Watch was set; as near as the Going of the Watch can be depended upon.

Maskelyne, when he became the fifth Astronomer Royal, also became *ex officio* a Commissioner for Longitude and it was his job to oversee the testing of Harrison's timekeepers.

In 1759 the large watch (H4) was shown to the Board of Longitude. It was to turn out to be the version on which Harrison would pin his hopes. He put it forward for testing and eventually it was to win for him the full prize offered. Its test was a voyage to Barbados and on 18 November 1761 Harrison's son sailed with it in HMS *Deptford*. He returned to Portsmouth in March 1762. The performance of H4 during the voyage to Barbados had been a revelation, for during a period of 46 days it had varied no more than 38.4 secs. In some respects the design of H4 did not reflect Harrison's beliefs about the use of oil, for he found it necessary to use oil at the pivot bearings and at the pallet.'[13]

What had Harrison done to produce a timekeeper with such a startling performance? First, he solved the problem of incorporating a device in a watch that compensated for the effects of changes of temperature. Instead of the gridiron devices of H1 and H2 a single bimetal strip was used as in H3.

The watch in which Harrison first incorporated temperature compensation, known as 'the Jefferys watch', also contained Harrison's maintaining power.[14] It is called the Jefferys watch because it was made under Harrison's supervision by John Jefferys who was allowed to put his name on it. This name is repeated on the cap, with the addition of the date 1753. The Jefferys watch has, in fact, all the features of H4 except the remontoire.

A remontoire, as used in H4, is a constant force device placed in the train near to the balance. It supplies the power to maintain the balance and is rewound at short intervals by the main source of power, thus largely eliminating the variations in power arriving at the balance due to the inevitable defects in the gear train and the running down of the mainspring. The remontoire in H4 is rewound every $7\frac{1}{2}$ seconds.

Harrison used the escapement that was available at the time, the verge, but further refined it so that it performed better than could ever have been considered possible.

Harrison was unable to avoid the need for oil at the escapement even though he used diamond for his pallets and a crown wheel of hardened and tempered steel.

The mainspring in H5,[15] Harrison's copy of H4, is still the original and has been tested by checking its output at the fusee. Despite the passage of time the output was found to be uniform to 1 %, a most remarkable achievement and a testimony not only to the matching of the fusee to the spring but also to the quality of the steel in the spring.

Steels

Just before the middle of the eighteenth century, an advance took place in the industrial world, which is usually ignored by historians of horology. Without this discovery, however, it is doubtful if John Harrison could have been so successful with H4. This advance was the production for the first time in Europe of good quality steel, crucible steel, needed for the steel springs in portable timekeepers.[16] Springs of hardened and tempered steel had always been difficult to make. Mainsprings in horological applications are particularly highly stressed and although balance springs are not so highly stressed, great stability is nevertheless required.

The art of making crucible steel was known to the Chinese and the Indians before the birth of Christ, but the secret of its manufacture was unknown to the western world until it was rediscovered in the mid-eighteenth century. The celebrated Toledo and Damascus steels were produced from a mixture of wrought iron and what was known as Indian Wootz steel. The two were twisted together and welded. Indian Wootz steel was made by placing hammered iron and wood in a closed clay crucible of about 500 g (1 lb) capacity. Then, to bring about the necessary carbonisation, the crucible was subjected to intense heat for several hours in a small conical clay furnace blown by bellows.

The main method of making steel in Europe until the mid-eighteenth century was to place iron bars upon a bed of granulated charcoal in a muffle furnace and subject them to intense heat for up to a week. The result was called blister steel because of its appearance. The carbonisation achieved in this way was superficial and irregular and the behaviour of the steel when worked upon was consequently unpredictable.

It was the poor quality of the steel mainsprings supplied to him that encouraged Benjamin Huntsman (1704–76), a clock and watch maker from Doncaster, to undertake a series of experiments between 1743 and 1746. The results of his labours were highly satisfactory, for he discovered how to produce crucible steel. The greatest difficulty he had to overcome was to make crucibles capable of withstanding the intense heat. He did not patent his discovery but instead tried, unsuccessfully as it turned out, to keep the process secret. However for many years the process was in fact confined to Sheffield, where its secrets were passed from father to son. At first Huntsman made steel only in small quantities, but by 1751 the demand for his steel was such that he gave up his trade as a watchmaker and started to produce crucible steel commercially at a factory in Worksop Road, Sheffield. Huntsman's work was crucial to the development of English chronometer making.

Although Harrison's H4 solved the problem of finding longitude at sea, it was a costly mechanism to produce and required the finest of craftsmen to adjust it to the necessary standards. English watchmakers, however, were quick to build timekeepers without these drawbacks. This is not to say that Harrison's mechanism was refined or redesigned so as to be easier to make, for his solution was not to be the pattern for the future.[17] Nor was Harrison the only contender for the British prize – another great English horologist, Thomas Mudge, was also working for it.

Thomas Mudge (1715–1794)

In 1754 a Swiss astronomer, Johann Jakob Huber, came to England, and in the following year engaged Thomas Mudge to make a timekeeper to his design, in order to compete for the longitude prize.

This timekeeper[18] embodied an original constant force escapement, but unfortunately Huber had to leave to take up an appointment in Berlin before Mudge had solved various mechanical problems connected with the proper functioning of the mechanism. Huber was subsequently unable to solve these problems on his own and appears to have abandoned the project.

During the period 1750 to 1770 Mudge was working on various applications of his lever escapement, amongst other things. The first known lever escapement was fitted in a remarkable clock which had a train remontoire, thermal compensation and a very accurate lunar indication. It is presumed that this clock, now in the British Museum's collections, was intended to compete for the longitude prize, but did not come up to Mudge's expectations, even though he carried out adjustments and alterations to it over a number of years.

Some of the technical features embodied in this clock are at variance with Mudge's *Thoughts on the means of improving watches*, first published in 1763, then rewritten and republished in 1765. Presumably by this time he had learned a good deal from the performance of the clock and had come to new conclusions.

In 1765 Mudge was appointed by the Board of Longitude to the Committee that was to examine Harrison's successful timekeeper H4. When the details of H4 were revealed they must have been a considerable stimulus to Mudge, who had already been grappling with the problems of accurate timekeeping along broadly similar lines. Mudge also appears to have been convinced that another successful timekeeper would be eligible for the minor awards – £10,000 and £15,000 – offered by the original Act of Queen Anne, under which Harrison had received the first half of the £20,000 prize.

The one major technical improvement which could have given Mudge the advantage over Harrison was the detached lever escapement, Harrison having used a modified verge escapement in H4 and H5. Mudge, however, did not persevere with the development of the lever escapement, pinning his hopes instead on his constant force escapement. This was because by about 1770 he had become convinced that the lever escapement had a fundamental fault in the way impulse was transmitted to the balance. In fact he was wrong, as other makers of detached escapements were later to prove, the fault being in his very heavy levers and the lack of draw in his escapement. Mudge explained his point of view to Count von Brühl, in a letter dated 2 June 1772, where he talked about Arnold's form of pivoted detent detached escapement: 'Whether the preference should be given to one [impulse] pallet or two, I think there is no room to doubt about. All other things remaining the same, two have certainly the advantage of one.' By this he meant that a lever escapement giving impulse in both directions of swing of the balance was preferable to a detent escapement giving impulse in one direction only. Mudge continued:

> for the simple idea we have, is to supply, constantly and uniformly, that motion, which the balance would otherwise loose in every part of its vibration; but as that cannot be done, the next that naturally occurs, is to give it impulse in some one part of every vibration, equal to its loss of motion in that whole vibration, but even that cannot be done without some little disturbance of the motion of the balance, which should if possible, be preserved simple...

With these remarks Mudge appears to have condemned all the known escapements, whether detached or frictional rest, saying that his own constant force escapement, on which he was working at the time, came as near as possible to fulfilling the requirement of making up for energy losses in the motion of the balance as they occurred. To summarise, Mudge obtained the idea for his constant force escapement from Huber in 1755, though it was presented to him in quite an impractical state. From about 1755 until about 1770 he was working in a desultory way on the lever escapement and concluded that it had a fundamental failing. In 1765 he saw what lay behind Harrison's success and become convinced that he could do better. All this led Mudge to leave his business mainly in the hands of his partner William Dutton in 1771, so that he could devote himself to the construction of his first marine timekeeper. In a sense he was the true successor to Harrison, using several of his ideas, including anti-friction rollers, thermal compensation applied to the balance spring and maintaining power incorporated in the fusee.

He was driven to employing a complicated solution instead of a simple one, because of his search for absolute perfection. Unfortunately, as with Harrison, his answer was, because of its very complexity, expensive to produce and furthermore required a superlative craftsman to make it successfully. However, he produced a timekeeper whose performance was truly excellent.[19]

The Development of the Chronometer in France

Pierre Le Roy (1717–85)

Pierre Le Roy was born in 1717. His father Julien was a celebrated clockmaker who invented a form of repeating mechanism used widely in French watches of the day. He also developed a most important device for watches, the 'all-or-nothing' piece, which ensures that a repeater, should it strike at all, strikes the requisite number of blows to accord with the time shown by the hands. He held the appointment 'Horloger du Roi' with apartments in the palace of Versailles and on his death in 1754 his son succeeded to this appointment.

In 1748 Pierre Le Roy communicated to the Académie des Sciences details of his invention of a detached escapement. He realised that however much the verge escapement was improved, its drawbacks were such that a completely new escapement was needed – one that was 'detached'. Experience was to show that despite Mudge's view to the contrary the best way to maintain the balance is to provide it with an impulse of as short a duration as possible, delivered at or near to the point of rest of balance, i.e. when the balance spring is virtually unstressed and all the energy of the oscillating system is in the momentum of the balance. For the remainder of the cycle the balance needs to be unconstrained and thus free from interference. Only in this way is there any likelihood of isochronous behaviour of the oscillating system. This type of escapement is for obvious reasons known as a detached escapement and includes the chronometer and lever escapements and combinations of the two. The modification required to enable the escapement to become detached is the incorporation of a third component, a detent or lever which enables the locking function to be separated from the impulse. Once this is done the balance is no longer required to prevent the escape wheel from moving, this function being provided by another piece which is only acted on by the balance for a short time and at the desirable point of the cycle. Impulse can also then be given shortly after unlocking occurs.

Le Roy invented both the bimetallic form of compensation balance and the one that is theoretically more perfect – the mercurial. In addition he was the first to explain a method of making isochronous balance springs. Le Roy was convinced that a compensation balance was preferable to a compensation curb because of a discovery he made about the isochronous qualities of certain lengths of spring. He realised that when the effective length of the spring changes, as it does when a compensation curb is used, the isochronous qualities of the spring might be inpaired. Although Le Roy's conclusions were not quite correct, the crux of the matter is that although a given balance spring will not necessarily give isochronous results, it may be possible to find certain lengths of the spring that will.

Le Roy's Marine Timepiece In 1769 Pierre Le Roy published a memoir[20] about a new invention, a most remarkable marine timepiece which included virtually all the elements of a modern marine chronometer. It contained his detached escapement, a version of the chronometer escapement with a pivoted detent and a mercurial compensation balance. It also had his isochronous balance spring.

The chronometer, which formed the subject of his memoir and which contained these radically new features, was to prove highly successful. Le Roy's chronometer had no fusee, for he believed that his isochronous balance springs made this refinement unnecessary. He made two chronometers and both were tested at sea in 1767 and again in 1768. They performed extremely well. One had an error of only 38 seconds in 46 days (compare this with Harrison's 38.4 seconds in 49 days).

Le Roy's machines were in some respects clearly in the same class as Harrison's from the point of view of performance, and yet were more simple in design. He was awarded a double prize by the Académie, one for the timekeeper and one for the memoir describing it.[21] However the Académie's report on the results of the trials delivered on 5 April 1769 concludes:

> '...the rate of M. Le Roy's watch observed at sea in several voyages...has appeared in general sufficiently regular to merit the reward for the author: the principal intention of which is to encourage him to new researches; for the Académie must not dissemble that in one of the trials which have been made of the watch, it appears to have accelerated, rather suddenly 11 or 12 seconds per day, even while on land; from this it appears that the desired degree of perfection has not yet been obtained.

With these comments in mind Le Roy continued his efforts to improve his timekeepers, although unsuccessfully, until he died on 25 August, 1785.[22]

Ferdinand Berthoud (1727–1807)

Ferdinand Berthoud was born on 19 March 1727 at Placemont in the canton of Neuchâtel, Switzerland. However like A. L. Breguet, who was also Swiss, he was to spend most of his life in France. He was originally destined for the church, but his mechanical ability was so outstanding that he was allowed to follow his true vocation. He arrived in Paris in 1745 to perfect his knowledge of clock and watchmaking, and there soon achieved a position of eminence. Berthoud began his work on marine timekeepers in 1762 and was fortunate to obtain soon afterwards the appointment of 'Horloger de la Marine', which carried with it a pension.

He completed his first marine timekeeper in 1763. Although a relatively crude machine it included, amongst other things, a gridiron compensation device. It was only after some time and much effort that he considered that he had a machine good enough to be tested at sea. This was his No. 8 made in 1767. It was weight driven, had a cylinder escapement with 'pirouette' and a gridiron compensation.[23] Its performance at sea, considering its theoretical unsuitability for the task in hand, was in fact very good. The following table gives an idea of its rates during the 1771–2 trial.[24]

Place	*Period*	*Daily Rate*
Brest	16–26 Oct. 1771	1.19 sec. gaining
Cadiz	22 Nov.–10 Dec.	0.05 sec. gaining
Teneriffe	24 Dec.–4 Jan. 1772	0.19 sec. gaining
Goree	16–25 Jan.	1.46 sec. gaining
Fort Royal	17 Jan.–26 Feb.	1.11 sec. gaining
Fort Royal	13 Mar.–7 Apr.	0.50 sec. gaining
Cape François	18–30 Apr.	0.63 sec. losing
St. Pierre	29 May–5 June	3.60 sec. losing
Copenhagen	19 Aug.–4 Sept.	0.54 sec. gaining
Brest	9–20 Oct.	0.04 sec. gaining

The extreme variation of daily rate in the course of the year was less than 6 seconds. MM. Verdun de la Crenne and Borda Pingré, who took part in the voyage and were commissioned by the Académie to report on the machine's performance, computed that the errors in longitude on arrival at the various ports would have been no more than:

Cadiz	$1'$
Teneriffe	$1\frac{1}{2}'$
Goree	$\frac{1}{4}'$
Praya	—
Martinique	$1\frac{3}{4}'$
Martinique again	$\frac{1}{2}'$
Cape François	$\frac{1}{4}'$
Iceland	$2'$
Copenhagen	$6'$
Dunkirk	$1\frac{3}{4}'$
Brest	$1\frac{1}{2}'$

Despite the success of this machine however, Berthoud was to discard all its features. Its successors were to be spring driven and a detached escapement replaced the special cylinder escapement. There was in fact a steady progress towards a modern form of escapement, the first being a pivoted detent. Whilst developing it, Berthoud also abandoned his gridiron compensation, using instead a compensation curb similar to Harrison's, and subsequently a compensation balance with bimetallic rims. His No. 37 made in 1786 had a pivoted detent escapement and compensation balance. It also contained a very useful device which Berthoud fitted to nearly all his machines, a means of locking the balance for transport. By 1782 his machines presented, both in appearance and mechanism, a very close approximation to the modern marine chronometer. Of the thirty-one chronometers which Berthoud made for the government a considerable number still survive. In addition to his inventions and practical achievements, Berthoud also published three major horological works: *Essai sur l'Horlogerie* in 1763, *Traité des Horloges Marines* in 1773, and *Histoire de la Mesure du Temps* in 1802.

Ferdinand Berthoud also worked on a pivoted detent escapement which impulsed at the balance rim. This was produced in about 1771, when John Arnold was developing his first pivoted detent escapement. Unlike those of Le Roy and Berthoud, however, Arnold's escapement impulsed a roller of much smaller diameter than the balance. Although this was to be the pattern for future escapements, Arnold did not consider the change of sufficient importance to patent it, probably considering that it was merely a modification of the French escapements.

Berthoud later used a pivoted detent escapement with a normal roller (1785), but by then Arnold had patented his spring detent escapement (1782) and T. D. Wright, on behalf of Thomas Earnshaw, had patented Earnshaw's version of the spring detent escapement (1783).

In addition to a large and remarkably varied output of timekeepers, Berthoud published ten volumes dealing with all aspects of their construction. This valuable documentary record runs to over four thousand quarto pages and includes more than 120 engraved plates. In 1807 Berthoud was succeeded in the business by his nephew, Louis Berthoud, and it is from the work of these two and A. L. Breguet that the highly original French school of chronometer making developed.

Louis Berthoud was also a celebrated chronometer maker and almost exclusively used the pivoted detent escapement in his work. In 1799 he won a prize for a chronometer showing decimal time and was subsequently awarded an annual grant of 10,000 francs by Napoleon on condition that he instructed five pupils in the art of chronometer making. To this end the first Ecole d'Horlogerie was set up in 1804, with Berthoud as its director.

One of his pupils was Henri Motel, who was to be another great French chronometer maker (cat. no. 16). Born in 1786, Motel supplied many chronometers to the Ministre de la Marine and in 1838 won first prize for his chronometer No. 198. In 1827 he won a silver medal at the Exposition de l'Horlogerie Française and in 1834 a gold medal. He retired in 1857 and died in 1859. One of his pupils was his nephew, Onesime Dumas, who wrote Motel's obituary.[25] Dumas took over Victor Gannery's chronometer interests, installing himelf in Saint-Nicholas-d'Aliermont and becoming in time the leading chronometer maker in France.[26]

Saint-Nicholas, despite its small size, even had its own transit instrument for checking chronometer rates. This was installed by Emile Delépine at no. 22 Route Dieppe.

A. L. Breguet (1747–1823)

Breguet was appointed 'Horloger de la Marine' in 1815 but was not as diligent in supplying the needs as he was expected to be. As a result the Ministry threatened to take away his title although the threat was never carried out. In fact Breguet produced about ninety chronometers, but seventy of these were sold privately. The Ministry was eventually forced to go to other makers to obtain the chronometers required.

Before his appointment as 'Horloger de la Marine', Breguet had only made a few experimental chronometers. Those after 1815 tended to have Earnshaw spring detent escapement, sometimes with two going barrels. Breguet also occasionally used the lever escapement. The chronometers were of exceptional quality[27] and were made between 1806 and 1834.

Although Breguet died in 1823 there is no sign of change either in the style or the quality of workmanship after his son, Louis Antoine Breguet, took over the business.

Breguet also made precision watches with chronometer escapements, which he called '*garde-temps*', and others with lever escapements. One of Breguet's greatest inventions was the tourbillon, where the entire balance and escapement was made to revolve at a rate of anything between one and six minutes. The object was to eliminate vertical positional errors. Although Breguet patented the invention in 1801, the first watch with a tourbillon to leave his workshops was that in an Arnold watch, No. 11, given to Arnold's son, John Roger Arnold, in 1808 as a memorial to his father, John Arnold (see cat. no. 176).

By 1800 Breguet had also invented the form of terminal curve applicable to the flat spiral balance spring, another fundamental step forward in precision watch making.[28] For examples of Breguet's work see cat. nos 83, 89, 92, 122, 123, 152, 167 and 176.

Chronometer Making in Spain

The Spanish government made an unsuccessful attempt to set up a workshop to make chronometers. As a result of interchange between Ferdinand Berthoud and the Spanish government, it was decided to select some suitable craftsmen to be apprenticed to Berthoud. The intention was that on their return to Spain they should be able to make and service chronometers. The further intention was that they should be turn train apprentices so that eventually the Spanish would become independent of foreign chronometer makers. The first Spanish chronometer maker was Cayetans Sanchez who, under the sponsorship of the Spanish government, was trained by both Ferdinand Berthoud and Emery. Unfortunately, seven years after his return to Spain as a fully competent maker, he died of the plague. Ill fortune dogged the undertaking from then on and chronometer making was abandoned in 1826.[29]

In 1864, as a result of a competitive trial, the Spanish government purchased eighty chronometers: thirty-eight by J. E. de Losada (a Spanish maker in London, where he had a considerable reputation), twenty-nine by Johannsen and thirteen by Dent.

Further Developments of the Work in England

A dramatic demonstration of the effective use of timekeepers at sea was given by the widely publicised voyages of Captain Cook in the 1770s. Cook took three chronometers by John Arnold on his second voyage and K1, Larum Kendall's copy of H4, on his second and third voyages.[30]

John Arnold (1735/6–99)

John Arnold appears to have turned his attention from the lucrative business of supplying watches to George III and his court to the problems of precision timekeeping in about 1768. Between that year and the early 1770s, he made a number of watches with ruby cylinder escapements and fitted with compensation curbs of various designs. Presumably the experience gained with this type of watch convinced Arnold that a radically new approach was needed. His experiments with detached escapements, starting with a modified form of cylinder then various kinds of pivoted detent, led to the invention of his spring detent escapement in about 1781. Some further development work with this escapement continued, particularly with the proportioning of the parts. It was to be used almost to the exclusion of other escapements for precision work, not only by him but also by his son, John Roger Arnold, until about 1830. At the same time, John Arnold continued to develop the temperature compensation devices used in his timekeepers. He employed various forms of compensation curb acting on the balance spring until about 1775, when he took out a patent, No. 1113, for a balance incorporating temperature compensation, and for a helical balance spring. In 1778 the 'double T' balance appeared and was used in the famous pocket chronometer No. 36. This chronometer was tested at the Royal Observatory, Greenwich, from 1 February 1779 until 29 January 1780. Its going was so exceptionally good that Arnold was allowed to publish the results, along with those of pocket chronometer No. 68, and in so doing confirmed his growing reputation. In 1780 the 'double S' balance appeared, followed by a series of progressively improved balances, including the 'OZ' and the 'Z'.

John Arnold also developed and patented the helical balance spring with terminal curves. Patent No. 1328, dated 1782, covered his spring detent escapement, as well as the 'double S' and 'OZ' balances. John Roger Arnold joined his father in partnership in 1787 and by the time the elder John died in 1799, a flourishing business was in operation to market their work, which incorporated all the recent innovations.[31] John Roger Arnold continued to make chronometers until 1830 (when he went into partnership with E. J. Dent), during which time he experimented with various balances, gold balance springs, etc., and investigated ways of overcoming the problems caused by magnetism. The quality of his pocket chronometers reached a peak in about 1807 with his No. 2000, but after that their quality steadily declined. For examples of the Arnold's work see cat. nos 4, 5, 6, 7, 8, 14, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 43a, 44, 45, 46, 47, 48, 49, 50, 51 and 176.

Thomas Earnshaw (1749–1829)

Thomas Earnshaw started work on chronometers, initially for other makers, in about 1780, some twelve years after John Arnold. The patent for his form of the spring detent escapement, No. 1354, was taken out for him by Thomas Wright in 1783, after a good deal of delay, see cat. no. 57.

Earnshaw was particularly scathing in his criticism of Arnold's balances: 'The Ballances made by Mr Arnold by rule of Thumb, Bending, Hammering, and Filing, without one single truth about them, must to the poorest Mechanick be inconsistent in the extreme, as no worse method can be taken...'. This quotation is taken from Earnshaw's explanation of his timekeepers, published by the Board of Longitude in 1806. Both makers used their own highly original method of balance making and although Earnshaw's criticism is justified from a theoretical point of view, in practice similar results were attained with both types of balance. Later makers adopted and developed the Earnshaw method of manufacture, since consistent results could be more readily obtained.

Earnshaw used both the helical balance spring and terminal curves as patented by John Arnold, but his spring material was hard-drawn or rolled steel wire set to shape by bluing on a brass former. In time such springs lost elasticity because they were not hardened and tempered. To overcome this problem Earnshaw arranged the terminal curves so that the spring would cause a gradual acceleration of rate as the amplitude decreased. This then compensated both for thickening of the oil at the pivots and for the steady decline in the elasticity of the spring.

Earnshaw produced two different qualities of pocket chronometer. His better timekeepers had a compensation balance and helical balance spring, the less good a plain steel balance, a flat spiral balance spring without terminal curve, and a type of compensation curb known as the 'sugar tongs'. Both kinds are illustrated and described in the catalogue and each is used in watches with similar escapements. Also included are two movements (cat. nos 69 and 70) with duplex escapements but having the two kinds of balance and compensation mentioned above.

Earnshaw was originally trained as a watch finisher, and at one stage in his career it was alleged that the success of his timekeepers was due to the high degree of superficial finish applied to the movement. This allegation led Earnshaw for a time to produce movements left virtually 'in the grey', that is with the least possible amount of superficial finish and no gilding. Only the parts in working contact were properly finished and polished, and these are almost invisible except to the trained eye. Needless to say, such watches went every bit as well as those finished in the usual way, since the superficial finish contributed nothing to their performance. Two of the movements in the collection (cat. nos 61 and 63) illustrate this phase of Earnshaw's work.[32]

To John Arnold and Thomas Earnshaw must be given the credit for establishing the supremacy of English chronometers, after Harrison and Mudge had carried out their pioneering work. It is not so clear in what proportions that credit should be divided. For other examples of Earnshaw's work see cat. nos 58–70 inclusive.

Developments after Arnold and Earnshaw

In 1806, the Commissioners of the Board of Longitude published *Explanation of Time-Keepers constructed by Mr Thomas Earnshaw and the late Mr John Arnold*. In so doing they made available to other makers the details and many of the secrets of construction adopted by the two pioneers of the modern chronometer. This was done with the express purpose of fostering and advancing the art and science of chronometer making. Further encouragement was given in the form of rewards of one kind or another, following trials of chronometers at the Royal Observatory, Greenwich. Most makers used the helical balance spring with terminal curves patented by John Arnold, but this was usually in conjunction with a form of Earnshaw's escapement and a bimetallic balance. However some makers based their chronometers closely on Arnold's plan and this is illustrated by those signed Tho^{s} Percival (cat. no. 53), and Perigal and Brown (cat. no. 55). Urban Jürgensen came to England and studied with John Arnold for a time before returning to his native Denmark. His use of Arnold's escapement is not surprising, but it is highly individual in form.

By the late 1790s chronometers were being used on ships belonging to the East India Company; as early as 1791 the Company's printed log-books had a special column where the chronometer readings were entered.[33] By the end of the 1790s the Royal Navy Board began to buy chronometers for its Academy in Portsmouth. In addition merchant and Royal Navy officers were eager to buy chronometers privately and in fact at that time probably represented the greatest single source of demand. In 1818 the control of chronometers in Britain was transferred from the Board of Longitude to the Hydrographer.

By 1821 it is known, thanks to a documented transfer of Admiralty chronometers that of 130 chronometers, ninety had been made by Arnold, fourteen by Earnshaw, and thus twenty-six by other makers. In the same year the Admiralty instituted a series of chronometer trials at Greenwich. The makers of the three best chronometers tested, provided that they reached certain minimum standards, were originally to be awarded £300, £200 and £100 respectively.

These trials, known as the 'Premium Trials', ended in 1835 as a result of difficulties in establishing who the 'maker' of each particular chronometer was. In place of these trials the Admiralty tested annually any chronometer submitted and purchased a number of the best, according to their requirements. The first trial of which there is a full record was held in 1822 at Greenwich; twenty-four chronometers were submitted. In 1827 fifty-eight were entered for the trial.

As an indication of how much larger the production of chronometers was in England than on the Continent, it is pertinent to quote the experience of F. G. W. Struve, who in 1844 published details of an exchange of chronometers between the observatories of Altona, near Hamburg, and Pulkova in Russia.[34] He recounts that he had considerable difficulty in collecting together the large number of chronometers required.[35] Consequently a number of chronometers had to be obtained from Muston of Bristol and from Dent in London. The chronometers used were: Dent 14; Kessels (Altona) 14;[36] Muston (Bristol) 9; Hauth 9; Breguet 8; Barraud 7; Trede (Berlin) 4; Arnold 4; Urban Jürgensen 3; Parkinson 2; Arnold & Dent 2; Broecking (Hamburg) 2; and one each from Parkinson & Frodsham, Winnerl, Magnin, Emery, Kessels, Brockbanks, Berthoud and Roskell. Of the eighty-six chronometers used about half were English even though the exercise was mounted in Germany.

From 1822 to 1830 Arnold made about one hundred marine chronometers but few pocket chronometers.[37] After Dent joined Arnold, the firm turned out about six hundred marine chronometers in the next ten years (1830–40).

Dent disolved his partnership with Arnold in September 1840. E. J. Dent's numbering of marine chronometers went from No. 1571 in 1841, to No. 3043 in 1869. This would indicate a production of about fifty a year.[38] In the 1850s the total French output was about one hundred a year and by 1889 had fallen to forty.

In 1889 the total English output was about three hundred a year.[39] By the end of the century Le Roy of Paris, the leading French manufacturer, complained that the government demand was negligible – about five a year – the French Admiralty having about six hundred chronometers in stock. By this time the marine chronometer industry in England had also shrunk. The firms still producing were Messrs Mercer, Kullberg, Johannsen, Dent, Usher and Cole, and Gardner. Of these Mercer and Kullberg were the main producers. In 1900, Mercer made 170 marine chronometers, both two- and eight-day.[40]

In 1914 the lack of demand led to the cessation of the Greenwich trials. In 1917, however, the government asked Frank Mercer to bring together all the resources of the British chronometer makers, so that production facilities could be pooled and the serious loss of chronometers due to sinkings at sea made good. The other firms still in operation were by that time Kullberg, Johannsen, Usher and Cole, and Dent. Kullberg and Johannsen sprung and finished some Mercer chronometers and Mercer in turn made some parts for them. The Mercer factory was by this time virtually self-sufficient, with a staff of fifty-eight.

When the First World War ended in 1918, orders for new marine chronometers virtually ceased and it was not until 1939 that chronometers were once again in demand. By the end of the war Mercer were making about three hundred 2-day and fifteen 8-day marine chronometers each year. The only other firms still making them were Ulysee Nardin in Switzerland, Wempe in Germany (Hamburg) and the two firms of Hamilton and Elgin in the USA.

Developments in the USA

The Railroad Watch

Precision watches were made in America mainly for the railroads and are actually designated railroad watches. They were made to exacting standards by all the major watchmaking concerns and from 1893 onwards had in the main to comply with, amongst other things, the following timekeeping requirements:

1. Be adjusted in five positions (a sixth was added later);
2. Keep time to ±thirty seconds a week;
3. Be adjusted for temperature variations between 40–95 °F.

Mr Webb C. Ball of the Ball Watch Company, Cleveland, Ohio, did more than any other person to establish the requirements for these watches, which were used by over fifty-four railroad companies in the USA, Canada and Mexico. Ball initially approved only thirty-seven different types of watch. Later in about 1915 this number was reduced to nineteen. The Ball Watch Company did not itself make railroad watches but ordered them from the following companies: E. Howard Co; Hampden Watch Co; Seth Thomas Clock Co; Waltham Watch Co; Hamilton Watch Co; Illinois Watch Co; Elgin National Watch Co and South Bend.

With the onset of the Second World War the US was hard pressed to obtain enough chronometers for its navy. Waltham and Elgin put watches into small chronometer boxes to act as a superior deck watch. Elgin's choice of movement was a railroad watch known as Father Time. It was free sprung with a lever escapement and had twenty-one jewels. Hamilton, however, went one stage further and produced a fully fledged chronometer.

The Hamilton Marine Chronometer

Although produced completely by machine it was otherwise standard, being based on a model made by Ulyssé Nardin. So perfect was the company's workmanship that the chronometer was usually able to leave the factory without needing to be adjusted in any way apart from having to be brought to time. This was due in large part to the stable balance and spring combination. The balance was not cut and thus was not subject to alteration in its characteristics due to fatigue. The Ni-Span-C balance spring was made entirely 'in house', being worked up by the firm from the billet to the fully finished spring.[41]

Pocket Chronometers

All the major marine chronometer makers, with the exception of Mercer (although they did make a few deck watches), made pocket chronometers. It seems likely that most English makers would have continued with the full plate calibre for pocket chronometers had not the demand for a slimmer and less cumbersome watch forced them to adopt the half or three-quarter plate construction. The turning point seems to have been in about 1850. Before that date comparatively few of the slimmer calibres were produced, though examples exist as early as 1830. There was strong opposition to this trend from many makers who were convinced that to compress a chronometer into a considerably smaller space was detrimental: correct proportions could not be maintained, the frame would be less rigid, the lubrication would break down sooner because there would he less space for the oil, and so on. However, many makers accepted the challenge, and some very fine, thin calibres were produced, later adapted to receive keyless work. Amongst the examples are those by Charles Frodsham (cat. nos 104, 105, 107 and 111).

The detent escapement lends itself particularly well to hand production and performs best when entrusted to a highly skilled and experienced adjuster. It has never been successfully mass-produced, except in recent times when marine chronometers have been made in large quantities by Hamilton in America. The difference in price between a pocket chronometer and the best quality lever watch will perhaps serve to illustrate how much more work went into the former. At the turn of the century the firm of Victor Kullberg offered their best pocket chronometers, in a full hunter gold case and with every refinement, at £80. Virtually the same watch, but with lever escapement, cost £60.

Continental makers also produced a limited number of pocket chronometers, both pivoted and spring detent. Some beautiful examples were made by Louis Berthoud (1750–1813), and also by Jean François Henri Motel (1786–1859). Breguet mostly used the spring detent escapement but on the whole continental makers favoured the pivoted detent escapement.

Urban Jürgensen (1776–1830) made about seventy-three chronometers and eight hundred watches and, although trained by Breguet, favoured the English style, probably due to the fact that he worked with Arnold from 1800–1. However, Jürgensen's sons, Louis and Jules, adhered to the continental tradition and continued to produce pivoted-detent watches of the highest quality. Although Jules signed his watches 'Jules Jürgensen Copenhagen', after 1834 they were made in Le Locle in Switzerland where he set up a factory.

Towards the end of the nineteenth century English hand-made watches were progressively less able to compete with those made wholly or in part by quantity production techniques. Gradually the numbers of highly skilled watch makers and finishers declined, culminating in the virtual cessation of the old apprentice system by the advent of the First World War. In the end, it was the combination of all these factors which caused the breakdown in the chain of production of pocket chronometers, and the almost total loss of the particular skills that went with it.

Dent's records show that pocket chronometers ceased to be manufactured soon after the turn of the century. The last tourbillon made by Charles Frodsham was produced in 1910, but what escapement the carriage contained is not recorded, although it was probably a lever. The last chronometer pocket watch by Charles Frodsham was made in 1907. Parkinson and Frodsham made their last keyless chronometer pocket watch in 1913.

Pocket chronometers are being made again in small quantities in England by George Daniels, and by Derek Pratt in Switzerland. Daniels has now developed a new escapement, which combines the most desirable features of both the chronometer and the lever into one escapement. Specialist pieces by individual craftsmen have, of course, also been made in the various horological schools in England and Switzerland, and in Glashütte near Dresden in the German Democratic Republic.

Marine Chronometers and Precision Pocket Watches with Lever Escapements

It is uncertain exactly when Thomas Mudge started work on the lever escapement, but the evidence suggests the mid 1750s. His point of departure was no doubt Graham's dead-beat escapement for pendulum clocks. By 1770 he had made perhaps half a dozen examples of the lever escapement and had developed the geometry to allow a larger amplitude of the balance. These early examples include the first lever clock; and a small travelling clock made for the Count von Brühl and later converted by Mudge from verge escapement to lever at the Count's request.[42]

Two lever watches are also known, one made for Queen Charlotte[43] which is in the Royal collection, and another made for Colonel Jones and cased after Mudge's death. The latter, now known as the 'Flint' Mudge, was subsequently converted to an Earnshaw detent escapement. At least two other examples are vaguely referred to amongst Mudge's letters to Count von Brühl. Count von Brühl (1736–1809), the King of Saxony's envoy to the court of St James from 1764 until his death, was Mudge's friend and patron, and did a great deal to obtain recognition for him. Between 1772 and 1787 they exchanged a series of letters, of which only those from Mudge have survived, published in 1799 by his son.[44] These letters give a unique insight into many aspects of Mudge's work and philosophy. Sometime after 9 August 1776, when the subject is mentioned in a letter, Mudge made a model of the lever escapement for Count von Brühl. This was for the specific purpose of publicising the escapement and encouraging other makers to use it, and demonstrates the Count's foresight.

As a result of Count von Brühl's efforts to publicise Mudge's original lever escapement, various makers tried to use it in one of several alternative forms; they included Josiah Emery, Richard Pendleton, John Leroux, John Grant, George Margetts, Francis Perigal, Taylor and T. Cummins (possibly Thomas) in England, and A. L. Breguet in France.

The English makers originally found the escapement difficult to make, and this probably accounts for the variety of forms adopted. Quite apart from the difficulty of making the parts themselves, there was also the problem of the choice of geometry to be used when designing the escapement. No one knew what the most suitable values for the angles were. With the exception of John Leroux, to whom credit is due, none of the early makers introduced 'draw' into the escapements. Draw is the slight inclination of the locking surfaces of the pallets so that they tend to make the lever move towards the wheel when locking occurs. This prevents any tendency for the fork to rub on he safety roller on the balance staff during the supplementary arc of the balance, and greatly improves the performance of the escapement. Without draw a pocket timekeeper fitted with a lever escapement produces random errors in timekeeping, depending upon how much disturbance to the balance occurs. However perfect the design of the escapement, the acting surfaces of the pallets need to be oiled and this inevitably produces a further instability. By about 1800 the detent escapement had proved its superiority for both pocket and marine chronometers. The hand-made lever escapement must have been initially far too expensive for ordinary watches, and was abandoned temporarily in England for precision use.

The link between the early levers for precision use up to about 1800 and the continued use and development of the escapement in England appears to be the work of Peter Litherland and Edward Massey in Liverpool. Litherland took out patents in 1791 (No. 1830) and 1792 (No. 1889) for various versions of his rack-lever escapement. In the second patent he clearly stated that the escapement was for application in timekeepers to be used at sea, where it would clearly be cheaper to make and repair than the escapements then in use. While he must have been disappointed in this expectation, the escapement gave perfectly adequate results in ordinary watches and a considerable number were made in and around Liverpool. Later Edward Massey worked on improvements to the fork and roller action, in place of the rack and pinion of Litherland's escapement. The traditional English ratchet-tooth lever escapement with table roller evolved from this work, the escapement parts for which were mostly manufactured in Liverpool and Prescot throughout the nineteenth century and the early part of the twentieth century.

The lever escapement, despite the fact that it has to be oiled, does have certain advantages over the detent escapement. It is less subject to positional errors caused by lack of poise than the spring detent and is more robust and less easily damaged by hard use or unskilful handling. The detent escapement cannot be reduced in size beyond a certain limit; one has never been successfully incorporated into a wrist watch. Once the correct proportions for the lever escapement had been established, and draw introduced, its rise in popularity roughly corresponded to the gradual improvement in the machinery available to produce its component parts. The lever escapement is best and most efficiently produced by accurate machinery, because there is little scope for adjustment once the parts are made.

New Developments

By the beginning of the 1960s the advent of the small quartz crystal clock and changes in maritime law meant that carrying a mechanical chronometer was no longer a legal requirement, an electronic timekeeper being accepted in its place. By 1968 the severe competition from quartz crystal controlled watches led to the cessation of the Swiss Watch Trials, which had become meaningless.[45] By 1969 the Hamilton Pulsar, the first watch without any moving parts, had been produced and the days of the precision mechanical watch and chronometer were numbered.

Notes

1. See Derek House and Valerie Finch, 'John Flamsteed and the Balance Spring', *AH*, March, 1976, pp. 664–73.
2. Christopher Columbus departing from the Canaries in 1492 carried with him a series of *Almanacs* or *Ephemerides* compiled by Johannes Mueller. These gave predicted positions of the Sun, Moon and planets as seen from Nuremberg from 1476–1506, later taken to 1531 by Johannes Stöffer (1452–1531) of Tübingen (Professor of Mathematics at Tübingen University). However the tables do no appear to have been very accurate, for Mueller seems to have made an error of $1\frac{1}{2}$ hours, some 23° too far to the west on one occasion and on another occasion $2\frac{1}{4}$ hours. We cannot be absolutely certain what contributed to these enormous errors.
3. F. Marguet, *Histoire de la longitude à la mer au XVIII siècle, en France*, Paris, 1917. In Chapter 19, 'Concerning a new method of finding longitude', he says:

> In our age we have seen some small clocks skilfully produced which are of some use. These, on account of their small size are no burden to a traveller. These will often keep running continuously for up to 24 hours. Indeed if you help, they will keep running as if with perpetual motion. It is therefore with the help of these clocks and by the following methods that longitude is found. In the first place we must take care that before we set out on our journey, we should observe exactly the time at the place from which we are making our journey. Then while we are on our journey, we should see to it that our clock never stops. When we have completed a journey of 15 or 20 miles, it may please us to learn the difference of longitude between where we have reached and our place of departure. We must wait until the hands of our clock exactly touches the point of an hour and at the same moment by means of an astrolabe or by means of our globe, we must find out the time of the place at which we now find ourselves. If this time agrees to the minute with the time shown on our watch, it is certain that we are still on the same meridian or in the same longitude, and our journey has been made towards the south. But, if it differs by one hour or by a number of minutes, by the method I set out in the previous chapter, and in this way the longitude is discovered. In this way I would be able to find the longitude of places, even if I was dragged off unawares across a thousand miles, and even though the distance of my journey was unknown. But then first of all, as always, the latitude must be learnt. I have already explained this before and also that it can be found out by various methods of finding out the time. Then indeed it must be a very finely made clock which does not vary with a change of air. (Trans. by Philip Kay)

In the 1553 edition a sentence is added which seems to be the first actual reference to longitude-finding at sea:

> Therefore it would be useful on long journeys, especially sea-journeys, to use large clepsydras (that is water-clocks) or sand glasses, which will measure a whole day exactly, through which the errors of the other clock may be corrected. (Trans. by Philip Kay)

The first description in English was a translation of the above by Richard Eden in 1555. (Richard Eden, *The Decades of the New Worlde*, London, 1555, f. 361). He adds his own postscript:

And so shall the longitude bee founde. Any by
this arte can I fynde the longitude of
regions althowgh I were a thou=
sand myles owt of my attempt=
ted course & in an unkno=
wen distance, but the
latitude must furste
bee perfectly
knowen.
FINIS

4. L. A. Brown, *The Story of Maps*, New York, 1951, p. 209.
5. See F. Baily, *An Account of the Revd John Flamsteed*, 112. Copies in PRO. (PRO/SP29/368, ff. 299 and 44, p. 10).
6. Galileo was virtually under house arrest at this time, being closely supervised by the Inquistition. His death in 1642 put an end to negotiations.
7. The Act of Queen Anne 1714 became law as 12 Anne., cap 15.
8. As soon as the pendulum had been invented (1657), it became evident that its rate varied due to changes in its length as the temperature altered. A clock with a brass pendulum rod will lose a quarter of a minute a day in the summer as compared with the winter. The substitution of a steel rod for a brass one will improve this situation and using a wooden rod will improve it yet again, provided the rod is well varnished to make it impervious to the effects of moisture.

The first compensation pendulums used the different rate of expansion of two metals to offset one another. The downward expansion of one metal is offset by the upward expansion of another so that the bob is kept a constant distance from its point of suspension. Two radically different compensation pendulums were developed at virtually the same time by George Graham and John Harrison. Graham's pendulum was of steel and mercury. The downward expansion of the steel is offset by the upward expansion of the mercury, which in Graham's example was contained in a glass jar. Harrison's pendulum, which was introduced about 1729 and known as the grid-iron, consisted of five rods of iron and four of brass. In essence, however, there are three rods of iron and two of brass, the arrangement of the greater number merely being for symmetry. Since the ratio of the coefficients of linear expansion of iron to brass is 11:19, the lengths of the rods merely have to be in the inverse proportion to this to achieve equal expansion and thus compensation.

This gridiron arrangement could also be used to alter the effective length of a balance spring by moving the regulator automatically.

9. For further reading on Harrison and the grasshopper escapement, see Humphrey Quill, *John Harrison, the Man who found Longitude*, London, 1966; William Laycock, *The Lost Science of John 'Longitude' Harrison*, Ashford, 1976.
10. Even as late as 1860 Airy, in the course of a report made to the Admiralty, remarked: 'C. Another very serious cause of error was brought out very clearly in this trial: namely, a fault in the oil, which is injured by heat... I believe that nearly all the irregularities from week to week... are in reality due to the two causes B (defective compensation) and C.' These remarks emphasise the important truth that the timekeeping of any chronometer or other precision timekeeper, even one of perfect design and construction, is at the mercy of its lubricating oil, and that it is accordingly all-important to use an oil which will not deteriorate for as long a period as possible. Many kinds of oil were tried – mineral oils, such as paraffin; vegetable oils, such as rapeseed oil; olive oil, and that extracted from various nuts; and animal oils, such as neatsfoot, porpoise and sperm oil. Mixtures of all the above were also used.
11. Charles Stanhope was the son of the first Earl Stanhope, who had played a leading part in the passing of the Longitude Act twenty-five years earlier.
12. Board of Longitude $5/12^{v}$.
13. Nevil Maskelyne, *The Principles of Mr Harrison's Timekeeper*, 1762, p. xvi.
14. Richard Good, 'Maintaining Power', *Clocks Magazine*, June, 1986, pp. 37–41.
15. Richard Good, *Pioneers of Precision Timekeeping*, Antiquarian Horological Society, Monograph No. 3, n.d.
16. Leslie Paton, 'Iron and Steel available to Horological Masters of the Past', *AH*, September, 1984, pp. 47–51.
17. Examples of Harrison's work are to be found in the National Maritime Museum, Greenwich, London, and others including the Jefferys watch are in the collection of the Clockmakers' Company at the Guildhall, London. See *Catalogue of Navigational and Astronomical Instruments in the National Maritime Museum*, Volume 1, p. 9.24. and *Catalogue of the Collection of The Worshipful Company of Clockmakers*, Cat. Nos 187, 551, 552 and 553.
18. This timepiece is now in the Basle Historical Museum.
19. Gould 1923, Appendix II, pp. 267–72.
20. *Mémoire sur la meilleure manière de mesurer le temps en mer*. At their session of 5 April 1769 the Académie des Sciences awarded the double prize to this memoir and the timekeeper accompanying it, which had both been submitted under the motto of *Labor improbus omnia vincit*. It was published in the following year as an Appendix to Cassini de Thury's *Voyage fait par ordre du Roi en 1768, pour éprover les montres marines inventées par M. le Roy*, Paris, 1770. (Cassini was an astronomer).
21. Charles Gros remarked in his book *Echappements d'Horloges et de Montres*, Paris, 1913, p. 125: 'Pour avoir obtenu la longitude avec un méchanisme qui fut abandonné tôt après, Harrison a reçu 500,000 francs; le Français de génie qui dota son pays d'une gloire de plus, qui sacrifia sa fortune et vingt ans de sa vie, reçut 'une médaille!' (trans. Gould, Marine Chronometer, p. 94). 'Harrison for finding longitude by a mechanism which was abandoned almost immediately received £20,000. The Frenchman of genius [Le Roy] who added more to the glories of France and sacrificed his fortune and twenty years of his life received a medal!'). This emotive claim is not correct, for Le Roy's prize was 4000 livres, although the pension granted of 1200 livres was only paid for three years, since the state then ran out of money.
22. Jean Lebot, *Les Chronomètres de Marine Français au XVIIIe Siecle*, Grenoble, 1983.
23. For full details of this machine and many others made by Berthoud, *Ferdinand Berthoud 1727–1807, Horloger Méchanicien du Roi et de la Marine*, Catalogue of the Musée International d'Horlogerie, La Chaux-de-Fonds, 1984).
24. Together with No. 6, a machine of almost identical construction, it was tested in a twelve months' voyage in the frigate *L'Isis*. An account of this voyage was afterwards published under the title *Voyage fait par ordre du Roi, en 1768 et 1769, pour éprouver en mer les horloges marines inventées par M. Ferdinand Berthoud, Par M. d'Eveux de Fleurieu*, Paris, 1773. At this period, it should be noted, Berthoud called his weight-driven machines 'Horloges Marines', and his spring-driven ones 'Montres de longitude'. They were again tested, in the frigate *Flore*, in 1771–2. An account of this voyage was published under the title of *Voyage fait par MM. Verdun, Borda et Pingré,...*, Paris, 2 vols, 1778.
25. Motel's obituary appeared in the *Revue Chronométrique*, Vol. III, 1859, pp. 79–82.
26. *Revue Chronométrique*, Vol. X, August 1879, f. 326 for further details. A chronometer by Victor Gannery (no. 13) is in the Musée des Arts et Métiers, as is one by Dumas (no. 20).

27 In 1824 the celebrated astronomer Dominique Arago presented in his scientific notices to the Académie details of the tests of some of Breguet's work at the Observatory in Altona. These tests were carried out by Heinrich Shumacher. Two clocks were tested and a chronometer, no. 3056, which showed a maximum deviation of only one second over a period of six months. For details of thirteen of Breguet's marine chronometers, see Daniels, 1975.

28. Daniels, *op. cit.*, pp. 329, 330.
29. C. F. Duro, *Disquisiciones Nauticas*, Vol. IV, Madrid, 1879.
30. E. G. R. Taylor, *Navigation in the Days of Captain Cook*, Maritime Monographs and Reports, 18, National Maritime Museum, Greenwich, 1975; Derek Howse and

Beresford Hutchinson, *The Clocks and Watches of Captain James Cook 1769–1969* (reprinted from four issues of *AH*, London 1969).

31. Mercer, 1972.
32. Mercer, op. cit., pp. 87–96.
33. W. E. May, 'How the chronometer went to sea', *A.H.*, Vol. IX 641–3; i.d., 'The logbooks used by ships of the East India Company, *Journal of Navigation*, 77 (1974), pp. 116–8; J. F. Cole, 'Chronometers and The Royal Navy', *HJ*, 58, November, 1915, pp. 28–35.
34. The object of the exercise was to compare the difference of meridians (longitudes) between Altona near Hamburg and Pulkova near today's Leningrad.
35. Jürgensen (1776–1830) remarked 'While Ferdinand Berthoud enjoyed the highest reputation in France and in all Europe for his beautiful productions in the art, the chronometers which the English exported to their neighbours across the water were admirable because of the simplicity of their construction, the making of the instruments after rules most applicable, most exact and true to theory and manufactured in much greater quantities than those of the French artists whose chronometers as exact measures of time left nothing to be desired.' In 1865 Lord Caithness said at a meeting of the British Horological Institute, that for every good chronometer made in France two hundred of superior quality were made in England. The French navy had the unfortunate habit of testing chronometers for two years and if they passed only then were they paid for, if not the maker had to try again. This practice obviously gave no great encouragement to French makers.
36. Heinrich Johann Kessels a Dane (1781–1849) was an Altona maker. Other Altona makers were: Theodor Knoblich (1827–92) and Moritz Krille (1817–63). An example of Krille's work, a two-day chronometer no. 1483, is in the National Maritime Museum, Greenwich.
37. Mercer, 1972, f. 172.
38. Mercer, 1977.
39. J. Tripplin, *Watch and Clock Making in 1889*, p. 43. Twenty chronometer makers showed their wares at the Paris Exhibition in 1889. They were for England: Kullberg, Usher & Cole, Parkinson and Frodsham and R. Webster; for Switzerland: Jürgensen, Nardin and Grandjean (apparently these Swiss makers used English movements, although how complete these were is not known); for Norway: Iversen and Frederick Michelet; for the United States: Heinrich; for France: Leroy, Delepine, Cailler, Fenon, Brown, Lefevre and Ratel.
40. Tony Mercer, *Mercer Chronometers*, Ashford, 1978, p. 40. Around 1880 sixteen men were employed for finishing, springing and assembling. Movements came from Prescot, either Pendleton, J. Preston or the Taylor brothers (John and Thomas, who signed: *J. & TT Alderton Rd Prescot*) and pinions from makers like Thomas Foster of St Helens and E. John Pendleton (Prescot). Balances came from George William Leonard of London, hands from James Hood (Clerkenwell) or J. Haigh & Sons (Prescot). Escapements and finishing by Bobby Silk and Henry Travers (both of St Albans), Edward Ovenden, Henry Field (St Albans) and Henry King (St Albans).
41. One of the standard Hamilton marine chronometers was fitted with a Harrison-type remontoire by David Evans of the Royal Observatory, Greenwich, in about 1955 and its rate checked against a Belin Chronograph. The performance of the chronometer was equal to that of a single quartz crystal clock in use at that time (personal communication by the late David Evans).
42. Now in a private collection in the UK.
43. Richard Good, *Pioneers of Precision Timekeeping*, Antiquarian Horological Society, n.d. Monograph No. 3, pp. 16, 31–45, 75–91.
44. Thomas Mudge jun., *A description with plates of the time keepers invented by the late Mr Thomas Mudge*, London, 1799.
45. Watches were tested in Switzerland from 1873 at the Observatory of Geneva and from 1875 at the Observatory of Neuchâtel. For details see E. Jaquet and A. Chapuis, *Technique & History of the Swiss Watch*, London, 1953, pp. 187–95 (English edition).

I

EARLY ATTEMPTS TO ACHIEVE ACCURATE TIMEKEEPING WITH A NON-PRECISION ESCAPEMENT

I (cat. nos 1–3)

The three watches in this section were made at a time when the problems of constructing accurate timekeepers had not been resolved; they represent the results of early stages in the thinking of two horologists who later achieved success and fame in this field. Two of the watches, cat. nos 1 and 2, have verge escapements and the third, cat. no 3, a cylinder escapement, thus they cannot be precision timekeepers. However all three are fitted with a form of temperature compensation and so form a link between non-precision and precision timekeepers. All three of the watches have fusees.

Ferdinand Berthoud, a Swiss national who spent most of his long working life in France, was one of the pioneers of chronometer making there and was succeeded by his nephew, Louis. A fine collection of marine timekeepers by Ferdinand Berthoud is preserved in the Musée National des Arts et Metiers, in Paris. Cat. no 1 by him contains a gridiron form of compensation based no doubt on Harrison's early marine timekeepers.

Josiah Emery continued Mudge's work on the lever escapement but the two watches by him, cat. nos 2 and 3, were made after his first watches with lever escapements. This suggests either that he was dissatisfied with the performance of the lever escapement or more probably that the cost of making it precluded its general use.

1 FERDINAND BERTHOUD
1763

VERGE WATCH *Plates 1a–e, 2a*

Signature: Around the edge of the dial plate 'Ferdinand Berthoud Inv et fecit 1763'. On the back plate 'Ferdinand Berthoud á Paris No 417'. The dial also signed.

Case: Gold consular style case with glazed back not opening, the glass missing, the glazed front bezel with book hinges of five knuckles, and a catch operated by a gold covered push-piece. Stirrup pendant with chased ring. On the pendant is an indistinct assay mark. Diam. 49·0 mm, h. over glasses 30·8 mm.

Dial and hands: Curved enamel dial signed on the back 'C^{u}J^{l}' with one positioning foot passing into a hole in the front plate, and a retaining screw near the figure III. The dial pierced for winding and inscribed Ferdinand Berthoud.

Gold minute and hour hands, blued steel sweep centre seconds hand.

Movement
Front plate diam. 41·8 mm; back plate diam. 38·6 mm; frame th. 10·0 mm.

Frame: Full plate construction built up on a massive front plate, which also serves as the dial plate. Four turned pillars, the back plate retained by pins. The front plate recessed under the dial to provide space for the motion work, the case catch and spring, the setting-up-work, the bolt and shutter maintaining power and also the three cocks providing the lower bearings of the offset centre, and third and fourth arbors. The minute wheel and pinion arbor also pivoted under a cock. The movement hinge let into a slot in the edge of the front plate. The brass components nicely gilded.

Fusee: Keywind fusee pivoted between the front plate and a cock on the outside of the back plate. English type of stop-work, the setting-up-work under the dial on the front plate, the barrel arbor with an extended square on that end only. Bolt and shutter maintaining power acting on the teeth of the second wheel. A brass plate pivoting on a steel spring acting on the brass plate then provides the power to return it; this keeps the watch going during winding.

Going train: The centre wheel offset, the motion work driven by a pinion on the third arbor. The fourth wheel and pinion planted at the centre of the frame and carrying the seconds hand on an extended arbor. The fourth wheel meshing with a steel wheel on the arbor of the contrate wheel. The centre and fourth wheels and the steel wheel on the contrate arbor appear to be of the same fairly coarse pitch. The third wheel is of finer pitch. All the brass wheel teeth show signs of having been at least finished with a file, perhaps actually marked and filed out completely. The brass wheels are gilded, the general finish of the train of very ordinary quality.

Escapement: Typical continental verge escapement with adjustable slide for equalising the drops. The verge itself is a later replacement of poor quality and finish.

Balance: Plain gilded brass three-armed balance of large diameter, 27·3 mm, with a stop pin set in the outer edge of the rim. Two pins set in the top of the back plate in the path of the one on the rim of the balance limits the balance amplitude to a maximum of about 230°.

Balance spring: Steel open coiled spiral spring of about $2\frac{1}{4}$ turns, in poor condition, and seems likely to have been either a later replacement or the original spring much altered and deformed.

Thermal compensation: A gridiron system, made up of six steel rods and six brass rods built into a framework, moves a brass block set on the free ends of the two middle brass rods relative to the frame. This frame is screwed to the back plate by two plain steel screws at one end and a shoulder screw at the other. The effective length of steel relative to brass is 88·6 mm of steel to 89·5 mm of brass; this is duplicated on either side of the centre line. The movement of the brass block is further magnified by a pivoted lever on a stud on the edge of the back plate, in the ratio of about 7:1. This can be varied by moving a brass block fitted onto the longer arm of the lever.

Above the balance staff upper bearings an index system is pivoted between two superimposed cocks screwed and steady pinned to the balance bridge. This is moved by the brass block mentioned above, against a light return spring. The index pins embrace the last turn of the balance spring and are formed on the end of a piece of brass pointing down from a polished steel plate. This plate can be moved in relation to the compensation system for mean time adjustment.

Balance stop: A polished steel arbor is pivoted near the edge of the frame at the 5 o'clock position on the dial. A short steel lever mounted on the squared end under the dial projects through the edge of the movement. On the other end projecting through the back plate is squared a thin brass lever to stop or release the balance at will, by acting on the outer edge of the balance rim.

Going-train counts:
Great wheel (fusee) 54 teeth
Centre pinion 12 leaves, wheel 64 teeth, 4 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 48 teeth, 4 arms
Contrate pinion 24 leaves, wheel 32 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work: Driven by a pinion of 8 leaves on the third arbor of the going train meshing with a brass cannon wheel of 64 teeth turning once per hour and mounted with a friction device below a steel wheel integral with the cannon pipe.

The wheel on the cannon pipe 30 teeth
Minute wheel 30 teeth, minute pinion 6 leaves
Hour wheel 72 teeth

The only provision for setting the hands to time is either by stopping the watch with the balance stop and restarting it again at the correct moment as indicated by the hands, or else by attempting to push the minute hand round with the risk of breaking it or damaging the other two hands.

The minute hand is provided with a pin set in the hole of the boss passing into a slot in the steel cannon pipe. On pushing the minute hand the cannon pipe and steel wheel turn against the friction spring, under the brass cannon wheel, and the remaining motion work and hour hand turn as well. The friction device is so strong in action that any attempt to alter the hands by this method would have a disastrous effect on the rate of the watch.

Provenance: Ilbert Collection (reg. no. CA1–276).

Note: Whilst it appears that this watch was intended by its maker to keep a close rate, there seems little doubt that it would have kept only marginally better time than a common verge watch of the period if this was well executed. The compensation would have suffered from stick-slip friction, and the balance and spring would have suffered from a distinct lack of isochronism.

This watch is, however, extremely interesting as being almost certainly the first Continental watch to be fitted with temperature compensation; also it is one of only two watches known with bolt and shutter maintaining power.

Harrison's maintaining power predates this watch and was fitted to the 'Jefferies' watch made under John Harrison's control in 1752. However, the first watch whose details were made public that contained Harrison's maintaining power was Harrison's watch known as H4, and the mechanism of this watch was not made public until after the manufacture of Berthoud's watch.

The case has been modified from a more conventional case which has been deepened to provide room for the temperature compensation device. Gould in *The Marine Chronometer* (p. 170), refers to the first pocket watch with a compensation curb as generally stated to have been sold by Berthoud to George III in 1763.

Bibliography: A. Randall, 'Ferdinand Berthoud', *AH*, June 1986; A. Randall, 'Analyse du Traité des Horloges Marines et du Supplément au Traité des Horloges Marines', *ANCAHA*, no. 30, Printemps 1981; A. Randall, 'Berthoud et l'influence de ces contemporains', *Chronométrophilia*, no. 17, Winter 1984; *Ferdinand Berthoud 1727–1807, Horloger Mécanicien du Roi et de la Marine*, exh. cat., Musée international d'horlogerie, La Chaux-de-fonds.

2 JOSIAH EMERY

1784

VERGE WATCH *Plate 2b–e*

Signature: On the back plate: 'Josiah Emery Charing Cross London No 1005'. Repeated on the dust cover. On the dial 'EMERY LONDON' across the centre.

Case: Silver consular case with the London hallmark for 1784 and maker's mark VW.[1] Diam. 54·8 mm, h. over glass 24·9 mm.

Dial and hands: Flat enamel regulator type dial.

Central minute hand with subsidiary seconds below and hours above. Blued steel hands.

Movement
Dial plate diam. 43·3 mm; front plate diam. 41·8 mm; back plate diam. 39·6 mm; frame h. 9·5 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, without a detachable barrel bridge. Separate dial plate attached to the front plate by three short feet and pins carrying the movement hinge. The case catch and spring mounted on the front plate under the dial. An elaborate dust cover retained by a blued steel clip. All the brass parts gilded.

Fusee: Keywind fusee with stop-work and maintaining power, the maintaining ratchet wheel brass, most unusually sunk into the thickness of the great wheel. The great wheel of considerably larger diameter than the bottom of the fusee and passing under the barrel. The setting up by worm and wheel mounted on the inside of the front plate under the barrel.

Going train: With the exception of the escape wheel, all the brass wheels gilded, including the great wheel. The pinions and arbors finished to the highest possible standard. The pivots of the third and fourth arbors on the front plate side carried in a separate bridge. The great wheel with the unusual number of forty-nine teeth.

Jewelling: The lower pivot of the fourth arbor in a pierced jewel with very small oil sink, set in a brass ring retained by screws. The pivots of the balance staff in pierced jewels with endstones.

Escapement: Normal verge escapement, the pivot of the escape pinion on the escape wheel end carried in a steel plate carefully set in the balance potance. As a result of the steel on steel contact the pivot is badly worn.

Balance: Gilded brass four-armed balance with eight gold screws set in the rim. Two pins, not set diametrically opposite in the rim, point inwards and act as stops against an extension to the balance spring stud.

Balance spring: Blued steel short spiral spring of $4\frac{1}{4}$ open turns, pinned to a gilded brass stud screwed to the end of a massive gilded brass piece overhanging the balance with its foot screwed to the back plate next to the foot of the dust guard round the winding arbor. No regulator.

Thermal compensation: A short bimetallic strip screwed to a gilded brass block, itself screwed to the back plate, carries a gold piece nearly half the total length on the free end. The end of the gold piece is bent down on the inside of the last turn of the balance spring, 90° round from the pinning point. Also carried on the gilded brass block is a brass piece having a long and short arm overhanging the balance. The longer arm has the end shaped to match the gold piece, on the outside of the balance spring. The shorter arm carries an adjusting screw operating on the longer arm.

Balance stop: Operated by a push-piece near the case catch and moving a polished steel stop-stud set in a blued steel arm screwed to the underside of the back plate. The stop operates on the underside of the balance.

Going-train counts:
Great wheel (fusee) 49 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 8 leaves, wheel 17 teeth, 3 arms
Beats per hour: 17,850

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1941 (reg. no. CAI-806).

Note
1. The case maker probably Valentine Walker.

3 JOSIAH EMERY
1787

CYLINDER WATCH *Plate 3a–f*

Signature: On the back plate and on the dust cover 'Josiah Emery Charing Cross London 1110'.

Case: Gold open face consular case with seven-knuckle hinge and screwed-on stirrup pendant. The maker's mark VW (see note 1, cat. no. 2) and with the London hallmark for 1787. The dust cover has to be removed before the movement can be swung out of its case. Diam. 51·9 mm, overall h. 24·2 mm.

Dial and hands: Flat enamel dial slightly curved at the edge, with subsidiary seconds, having two short rectangular feet passing into slots in the dial plate and held by screws set in the edge of the dial plate. The edge of the dial plate engine-turned.

Gold minute and hour hands, blued steel seconds hand.

Movement
Dial plate diam. 44·5 mm; front plate diam. 40·2 mm; back plate diam. 37·9 mm; frame h. 7·5 mm.

Frame: Full plate construction with five turned pillars, the back plate retained by pins. The front plate secured by three screws to the dial plate, the screws passing through the edge of the latter and into blocks standing on the front plate. The movement hinge is integral with the dial plate and the elaborate blued steel case catch and return spring are secured to it. A balance stop operating lever and spring are also fitted under the dial plate with a push-piece projecting through the edge just after the III o'clock position. The balance stop connects with a yoke-crank on the end of an arbor pivoted in the frame, and carrying the stop piece squared and pinned to its other end. The elaborate turned dust cover, probably made from a number of pieces soldered together, is fixed to the back plate by a semicircular polished steel clip engaging two pillars standing on the back plate. In addition to the signature there is an engraved regulation scale with 'Fast' and 'Slow'. All the brass parts are gilded, including the dust cover and the edge of the dial plate. The balance cock engraved and with a segmented cut-out in its foot to clear the limiting stop of the dust cover catch. This stop no longer protrudes so that the cut-out is not required.

Fusee: Keywind fusee, with winding square surrounded by a dust-excluding tube, the foot of which obscures part of the engraving on the back plate. The usual stop-work and maintaining power are fitted; the block for the stop-piece is elaborately worked. The maintaining ratchet wheel is of brass and the polished steel maintaining detent is pivoted under the great wheel, the ratchet with integral spring. The setting-up-work is fitted on the front plate under the barrel which has a narrow flange. The barrel arbor is provided with a square hole on the dial side for setting up with a male key.

Going train: Compressed into the somewhat restricted space shared with the repeating train and hammers, it was not possible, apparently, to lodge the fourth wheel in the correct place for the seconds hand. A separate pinion is driven by a third wheel, carrying the seconds hand on an extended pivot and planted between cocks on either side of the front plate. A light spring bears on the arbor of this pinion to take up the backlash in the gearing. The train count itself is chosen to give the very unusual number of beats per hour of $17{,}966\frac{2}{3}$ of the balance and spring. The finish of the polished steel pinions and arbors is of a very high quality. The brass wheels are gilded.

Jewelling: The pivots of the escape pinion arbor and balance staff run in pierced jewels with endstones. A diamond endstone set in a polished steel ring is secured by two screws in a sink on the balance cock.

Escapement: A cylinder escapement in which the part of the cylinder acting with the escape wheel teeth is made from a semicircular piece of ruby set in a delicate steel frame carrying the lower pivot. The escape wheel is made of steel. Banking for the balance, to restrict its movement to somewhat less than a turn in either direction, is provided by a brass pin set in the top of the balance rim and two gold pegs set in the underside of the balance cock table, in the path of the pin.

Balance: Gilded brass four-armed wheel, the arms sunk below the level of the rim, and a large central boss sunk out below the level of the arms. Four gold timing screws are set in slotted holes in the rim, and two threaded gold pegs in plain tapped holes at the ends of one of the arms.

Balance spring: Blued steel helical spring of $4\frac{1}{2}$ turns without terminal curves attached at its lower end to a brass collet similar to that of Emery, cat. no. 9. The brass stud overhanging the balance also similar to that of Emery, cat. no. 2. Both collet and stud clamp the ends of the spring without distorting it from the original radius.

Thermal compensation: A segment-shaped piece of gilded brass is screwed to the back plate next to the balance cock. It carried a movable piece with rack teeth concentric with the balance centre engaged by a pinion with a squared arbor for mean time adjustment; this once had an index mounted on it which registered against the scale on the dust cover. Carried on the rack is a brass arm, and beside it a single straight bimetallic strip which has been repaired and may not be original. The brass arm is divided in two, with a thick portion carrying a screw to move the free end of the thinner portion towards or away from the free end of the bimetallic strip. The bimetallic strip is made up of steel and brass soldered together and appears to have been difficult to make. The flux has corroded along the edge and there is a good deal of distortion. The free ends of both the bimetallic strip and the thin brass piece next to it are formed with a part pointing down to embrace the last coil of the balance spring. The whole system is a developed version of that fitted to Emery, cat. no. 2.

Repeating work: Half/quarter dumb repeating of Stogden type, operated by pumping the pendant. This action causes a toothed rack to turn a pinion on the barrel arbor of the repeating mainspring, lodged in a barrel within the frame. All the steel parts of the repeating work are highly polished on their upper surfaces, and several on their lower surfaces as well. The edges are finely grained.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 60 teeth, no crossings
Third pinion 8 leaves, wheel 56 teeth, 4 arms
Fourth pinion 6 leaves, wheel 55 teeth, 4 arms
Escape pinion 6 leaves, wheel 14 teeth, 4 arms
$17{,}966\frac{2}{3}$: Beats per hour

There is an additional pinion of 7 leaves driven by the third wheel and carrying the seconds hand on an extended pivot. Since the gear ratio between this pinion and the centre wheel is 60:1 it will rotate once per minute.

Repeating-train counts:
Great wheel 42 teeth
Second wheel 34 teeth, pinion 6 leaves
Third wheel 34 teeth, pinion 6 leaves
Fourth wheel 30 teeth, pinion 6 leaves
Fifth wheel 25 teeth, pinion 6 leaves
Fifth pinion 6 leaves

Motion work:
Cannon pinion 4 leaves, minute 'pinion' (a brass wheel) 32 teeth
Hour wheel 32 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1938 (reg. no. CAI-1882).

II

THE INVENTION AND DEVELOPMENT OF PRECISION ESCAPEMENTS

II.i (cat. nos 4–8)

THE INVENTION OF JOHN ARNOLD'S PIVOTED DETENT ESCAPEMENT

The development and evolution of John Arnold's escapements from detached cylinder via see-saw detent to pivoted detent, and finally his form of spring detent are described by Vaudrey Mercer (see Bibliography). The Museum's collection does not include an example of either of the first two categories. The third type, with which we are concerned in this section, was evolved by John Arnold apparently independently of similar escapements invented in France by Pierre le Roy and Ferdinand Berthoud (see Historical Introduction). According to Mercer, Arnold's earliest use of a pivoted detent was in 1771 for a pocket chronometer, followed by a marine chronometer in 1774. The earliest in the collection is John Arnold No. 3, a pocket chronometer of 1773.

MAINTAINING POWER

In his earliest chronometers John Arnold used a keywound fusee with sun-and-planet maintaining power. This proved unreliable, and jammed on several occasions, probably owing to the inadequate strength of the planet wheel pivoting. As a result he adopted Harrison's type of maintaining power in about 1775 or 1776. Sun and planet maintaining power does have an advantage over Harrison's in that the driving force to the train is slightly increased during winding, whereas in Harrison's it is reduced. Most of the chronometers in this section have Harrison's maintaining power, with a brass ratchet wheel and a steel detent. The return spring for the detent usually consists of a short piece of steel wire set in the back plate, pointing inwards, with its free end engaging the detent. Setting-up-work for the mainspring is lodged between the barrel and the front plate, inside the frame. The setting-up click and return spring are made from a single piece of steel.

JEWELLING

Arnold did much pioneer work in the use of jewelling for working surfaces wherever possible and practicable. The pierced jewels used for train and escapement pivot holes are made from discs of natural ruby or sapphire, flat on both sides, and with almost no reservoir for containing oil. They are set in brass rings which are themselves held in recesses in the frame part by small steel screws. Escapement pivots usually have the end thrust taken on a flat endstone jewel set blind in a brass disc. In Arnold's early work the pierced jewel is not convex towards the endstone, which would assist in oil retention. However, he quickly realised the importance of this convex face which helps to retain the oil by capillary action and may well have substituted convex pierced jewels for flat ones when modernising older chronometers. Examples of both are described in this section. The balance cock normally has a rose diamond endstone set in a steel ring to take the end thrust of the balance pivot and to reduce still further the effects of wear at this vital point.

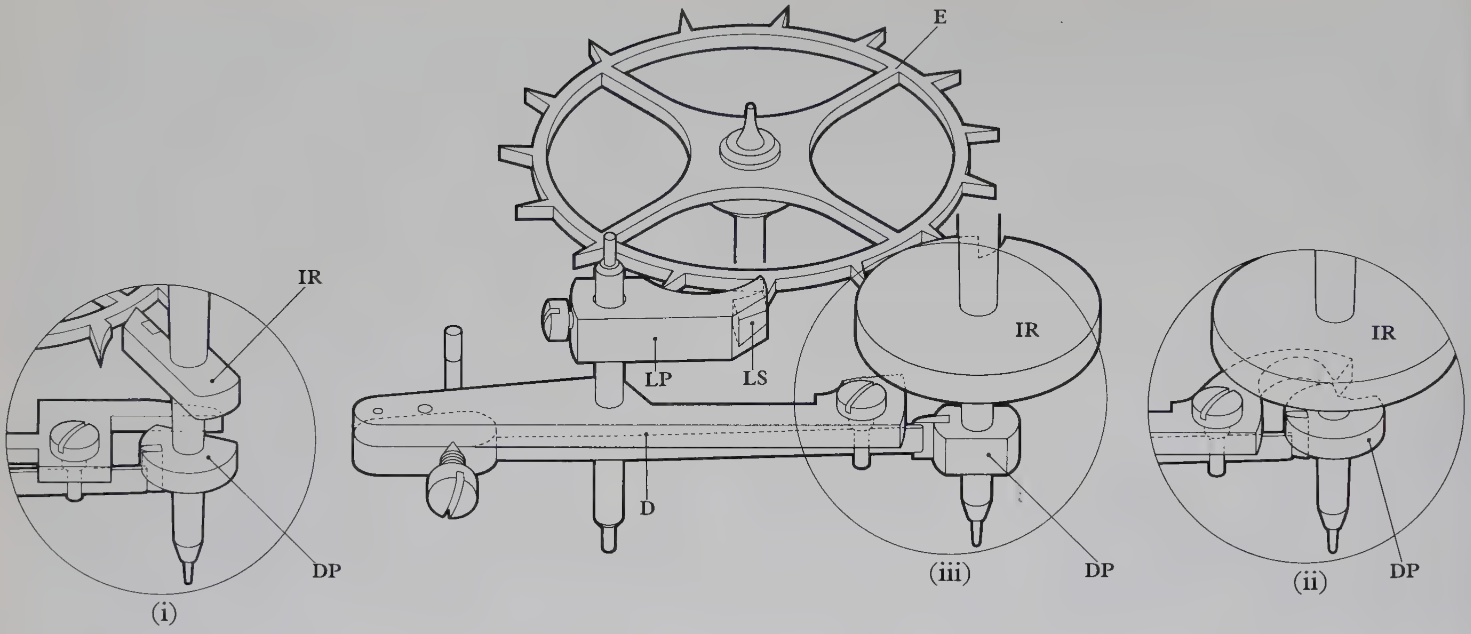
TEMPERATURE COMPENSATION

John Arnold's series of gradually improved forms of compensation balance are described in detail in the Appendix. Balance springs and terminal curves are also discussed in this Appendix.

PIVOTED DETENT ESCAPEMENT

The basic principles of the functioning of the escapement can be understood by studying fig. 1a.

Arnold's pivoted detent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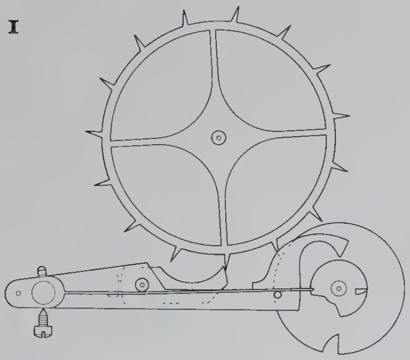
1



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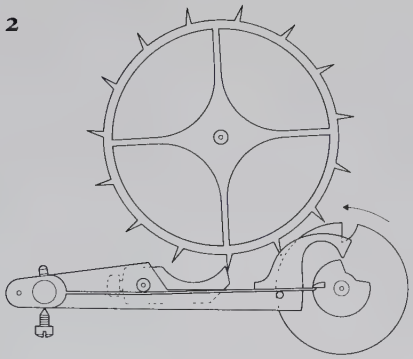

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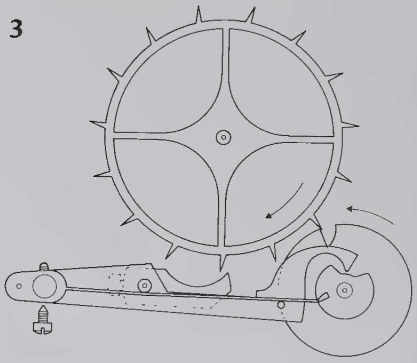

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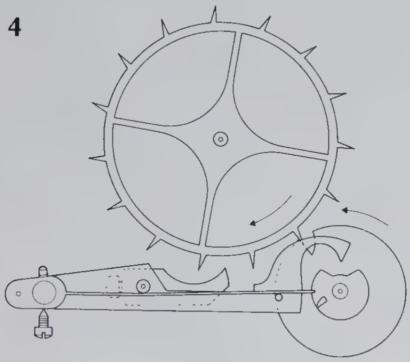

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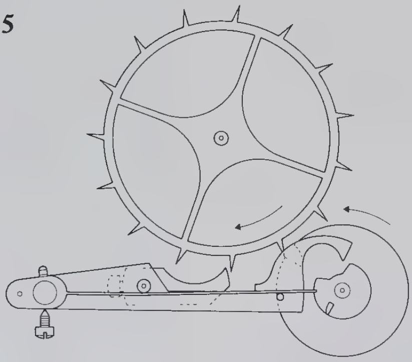

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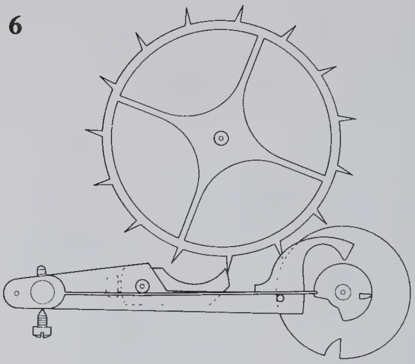

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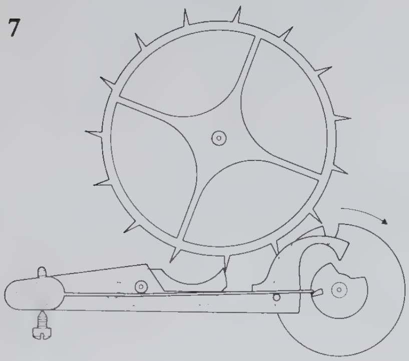

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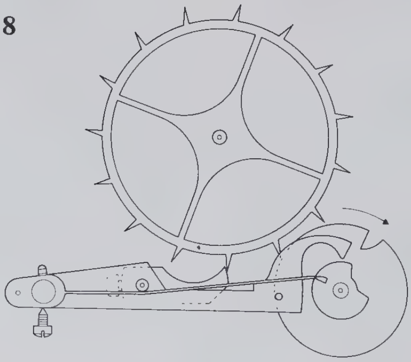


DRAW

In John Arnold's pivoted detent escapement there is no draw between the locking arm or jewel and the escape wheel teeth. This feature appeared for the first time in his spring detent escapement. The lack of draw increases the likelihood of accidental unlocking as there is no specific force tending to keep the detent against its banking.

SAFETY ACTION

John Arnold tried two similar arrangements of safety action, before arriving at a final form as in his No. 29. The earliest, as in his No. 3 (see inset (i), fig. 1), consists of an extension 'finger' to the end of the detent D, and a 'flat' on the side of the discharge roller. The detent can only unlock when the 'flat' is facing the 'finger', and the impulse 'pallet' R is in the correct position to receive an escape wheel tooth. Unlocking is prevented at any other time by the 'finger' touching the edge of the discharge roller. Originally No. 29 probably had an alternative safety action working on the same principle as that described for No. 3, but more critical and therefore more reliable in action (see inset (ii), fig. 1). Unfortunately both these safety actions will permit the escapement to unlock during a small part of the return vibration of the balance. Such an event would not occur under normal circumstances but could be provoked by an external shock. John Arnold therefore used the disc impulse roller in place of an impulse pallet, and dispensed with devices acting on the detent to prevent unlocking at the wrong time. With this safety action it is impossible for the detent to release at any moment other than the correct one for the transmission of impulse. The escape wheel will advance until a tooth touches the highly polished edge of the impulse roller, where it will remain until the notch arrives and allows it to pass safely and the wheel to re-lock. Although the balance amplitude, and hence the timekeeping, will be disturbed, there will be no damage to the escapement.

FIGURE 1 *(top left)*
The John Arnold pivoted detent escapement

(i) impulse and discharge arrangements of John Arnold No. 3
(ii) present state of John Arnold No. 29
(iii) probable original safety action and impulse pallet of John Arnold No. 29

D	detent
DP	discharge pallet
IR	impulse roller
LP	locking pallet
LS	locking stone

FIGURE 1A *(bottom left)*
Sequence of functions of John Arnold's pivoted detent escapement

1 Escapement locked; balance at rest at its clockwise extreme
2 Balance returning anticlockwise; discharge roller about to move detent and release escape wheel
3 Escape wheel released and about to give impulse
4 Impulse proceeding; released detent returns ready to re-lock escape wheel
5 Impulse completed; drop occurring escape wheel about to re-lock
6 Escape wheel locked; balance at rest at its anticlockwise extreme
7 Balance returning clockwise; discharge roller lifts passing spring without disturbing detent since a long and thus weak length of passing spring is being acted upon
8 Passing action nears completion; balance continues clockwise

PALLET JEWEL

In the two insets (i) and (ii) of fig. 1, each impulse pallet is shown with a jewel set back from the acting end. The jewel in fact runs diagonally across the impulse face towards the tip, as in fig. 1 (iii).

CONCLUSION

Two of the pocket chronometers in this section are fitted with repeating work. This is somewhat surprising because its operation could cause at least slight disturbance to the running of the chronometer. The space needed to lodge the parts would also reduce that available for the going part of the chronometer. In Arnold's defence it must be said that his chronometers so fitted are large enough to allow sufficient space for all the elements. He was probably acceding to the demands of certain wealthy and influential clients who requested this feature.

The work of John Arnold is characterised both by its steady evolution and by the avoidance of unnecessary complication. He is not known to have used any kind of revolving escapement, train-remontoire or constant force escapement. The variety in his early escapements and balances indicates his search for correct principles, and his powers of analysis and deduction must have been of the highest order. Having established with certainty what the correct principles were, he steadily progressed towards the perfection of every detail. He was also in the habit of updating chronometers when they were returned to his workshop, a practice which does not help in the evaluation of his work.

Bibliography: Mercer 1972.

4 JOHN ARNOLD

c. 1773

CHRONOMETER *Plate 4a–d*

Signature: On the back plate 'John Arnold, London Inv. et Fecit No. 3'.

Case: Later silver consular case, with fly springs and pendant lock to open the back. Fake hallmarks inside the back only, probably intended to represent those for London in 1812. Joints not fitted with the usual bearers. Diam. 55.0 mm, h. over glass 32.26 mm.

Dial and hands: Later enamel dial, unsigned on either side but with SS on the underside fired in, held by three feet and pins in crudely recessed sinks in the dial plate.

Centre seconds hand carried between the minute and hour hands. The minute hand broken off but was not original, being fitted on a squared tube which is itself adjusted on a square on the cannon pinion. The gold hour hand probably original, with the pipe removed from the boss, and soldered to a brass tube adjusted on the hour wheel pipe. The blued steel seconds hand also appears to be original.

Movement

Dial plate diam. 54·6 mm; front plate diam. 48·6 mm; back plate diam. 47·1 mm; frame h. 10·0 mm.

Frame: The dial plate made up from a disc and a ring hard soldered together and gilded on the visible parts, possibly using part of the original dial plate for the inner part. The movement hinge held by rivets on the dial plate. The case catch fitted on the inside of the front plate. A slot for a previous catch has been filled and gilded over, leaving a block standing proud on the dial side. This block later filed down somewhat, removing the layer of gilding on that part. Remainder of the frame conventional, with four pillars and pins, the brass parts gilded. There are various unused holes in the plates including some that were filled before gilding. The cock relieved to clear the new clickwork for the going barrel.

Fusee now changed to going barrel: The fusee was originally planted in the holes now occupied by the going barrel, the holes for the original barrel are no longer used. Setting-up-work was fitted under the dial, and marks around the holes indicate its presence there before the conversion. This is confirmed by two setting-up dots by the arbor pivot hole on the back plate. The fusee stop-work block removed by being broken off flush with the back plate. The original fusee did not have Harrison's maintaining power since there are no pivot holes for the detent or other holes for the returning spring. It must have had sun-and-planet maintaining power similar to John Arnold No. 11 (cat. no. 176). This probably failed at some stage and a repairer carried out the conversion in the simplest possible way. The original fusee great wheel has been used for the going barrel. The holes for the clicks, their springs and the internally cut wheel rivets are all visible. The wheel has been turned out on the inside for the barrel, fixed in place with soft solder. On the back plate two sinks have been turned to receive the barrel arbor steel clickwork.

Going train: Arranged to drive the centre seconds hand from a pinion on the escape arbor. The lower pivot of the escape arbor passes through a hole in the front plate and the pivot is supported by jewelling in a small cock on the dial side. Enough of the gilding is intact and together with the jewelling indicates that all this is original. Each wheel has a turned ring on both sides at the roots of the teeth, and all are gilded, though little remains on the great wheel except on the teeth.

Jewelling: The fourth and escapement arbor pivots in pierced jewels. The escape wheel arbor and balance staff lower jewels with endstones in wedged settings, the upper escape jewel with an endstone set blind in a brass plate. The balance cock endstone and setting not original. Where original, the pierced jewels are flat on both sides and without oil sinks. A slight chamfer at each end of the hole is the only reservoir for oil. Both balance staff pierced jewels have been replaced. The locking face of the detent and the impulse and discharge rollers on the balance staff jewelled with dovetailed jewels on their working surfaces. The discharge roller jewel parallel to the staff and standing proud on the lower pivot side of the roller. The impulse jewel set diagonally in the pallet.

Escapement: Similar to John Arnold No. 29 cat. no. 5, but with different safety action (see fig. 1 (i)). Steel escape wheel polished on both sides, the teeth leaning towards a radial to their tips, the rim section between the teeth polished in a swing tool, the crossings polished by hand. The detent passing spring and locking pallet of polished steel, almost poised, slightly tail heavy, returned by a short spring projecting from the potance and banked by a screw in the side of the potance.

Balance: Later Arnold 'double T' in substitution for the original plain balance and compensation curb, and almost certainly changed by Arnold himself. There are no supporting trammels for the rods carrying the gold compensation weights nor any sign of an amplitude limiting device (see cat. no. 6). Arnold was using the 'double T' balance beween about 1778 and 1780. The gold compensation weights are surprisingly far out on the balance. Diam. of rim 25·5 mm. h. 0·72 mm.

Balance spring: Previously a spiral spring, now a blued steel helical spring of $6\frac{1}{3}$ turns without terminal curves. This is particularly interesting as it illustrates the stage before Arnold invented terminal curves. Both the collet and stud pinnings are at the same radius as the spring which wobbles violently when set in motion. The very crude stud is obviously not original.

Balance cock: The foot cut away to clear the going barrel ratchet and clickwork. Various empty holes around the jewelling were probably used for the screws and pins of the original compensation curb and balance spring stud.

Train counts:
Great wheel (fusee or going barrel) 50 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 8 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 64 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, Minute pinion 14 leaves,
Hour wheel 42 teeth, Minute wheel 48 teeth

A pinion of 10 leaves on the escape arbor drives a wheel of 100 teeth, carrying the centre seconds hand and running loosely on the cannon pinion.

Provenance: By purchase (reg. no. 1974, 9–12, 1).

Note: This is the earliest known surviving pocket chronometer by John Arnold.

5 JOHN ARNOLD
1776

CHRONOMETER *Plates 4e–f, 5a–c*

Signature: On the back plate 'John Arnold Inv^t et Fecit No 29'

Case: Silver-gilt consular case with fixed back, no dome and a swivelling pendant. London hallmark for 1776, maker's mark MR. The winding hole in the case back covered by a disc which can be moved aside for winding. Diam. 63·7 mm, h. 30·3 mm.

Dial and hands: Enamel dial, with hairline crack, inscribed JOHN ARNOLD LONDON.

Flat blued steel hands, minute hand boss squared and hand retained by screw.

Movement
Dial plate diam. 52·5 mm; front plate diam. 48·3 mm; back plate diam. 56·7 mm; frame h. 10·1 mm.

Frame: Separate dial plate with four short turned pillars pinned to front plate. Hinge attached to dial plate at 12 o'clock. Case catch opposite and mounted with its return spring on the inside of the front plate.

Various unused holes in the movement are either empty or plugged, the reasons for this now only a matter for conjecture. A square hole is cut in the front plate to clear the escape wheel potance table.

Scratched in fine cursive script on the front plate beneath the dial under the minute wheel: 'Repaired and improved by Haley, Wigmore St., Cavendish Square, London'.[1]

Fusee: Fitted with Harrison's maintaining power and fixed on its arbor by a steel plate which is friction tight on the arbor and not by the more usual transverse pin. Maintaining ratchet wheel steel. Maintaining ratchet spring a piece of wire friction tight in the top plate.

Jewelling: Third, fourth and detent arbor pivots in flat pierced jewels. Very small oil sinks. Balance and escape wheel pivots in domed jewels, with endstones set blind into brass end pieces. Locking pallet and discharged roller also jewelled.

Escapement: Pivoted detent escapement which appears to be original,[2] described and illustrated in the Introduction. Very light ungilded escape wheel. Detent and escape wheel planted between the back plate and separate potances. Balance not original – this was probably a plain balance without compensation with flat spiral steel spring. The compensation probably provided by a bimetallic curb fitted to the balance cock foot, as the two unfilled holes in the cock would seem to indicate.

Balance: The present balance was quite possibly put in by Arnold himself as he frequently updated his work. It is an early 'z' type with brass crossbar with a short integral T-piece at each end screwed to a bimetallic rim (perhaps silver and platinum) with a screw at the free end of each rim for adjusting the compensation.

Gold regulating screws with threaded holes pass through clearance holes in the rims and engage with threaded rods that are integral with brass pieces that in turn are screwed to the crossbar. Diam. of rim 21·0 mm, h. 0·85 mm.

Balance spring: Steel helical spring with 7 complete turns and terminal curve at each end. The upper end attached to an overhanging glided brass stud with round hole screwed to the back plate, this stud obscuring part of the engraving. Collet also brass, with a round hole for the pin.

Balance cock: Has a symmetrical foot. The screws for the jewelling now pass through the table of the cock and into tapped holes in a blued steel plate fitted to the underside of the table.

Train: Appears to be original. The third and fourth wheel teeth show signs of having been 'topped' to a more pointed tooth form.

Going-train counts:
Fusee great wheel 48 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves
Hour wheel 60 teeth, minute wheel 64 teeth

Provenance: Ilbert Collection; Ilbert purchased this chronometer from Christie's in 1933 (reg. no. CAI-1838).

Notes

1. Charles Haley is recorded in Baillie 1951 as working in Wigmore Street from 1781 to 1825 and Free of the Clockmakers' Company in 1781, whilst John Arnold was negotiating to be made Free. He was one of those called upon by the Commissioners of the Board of Longitude to examine John Arnold's description of his timekeepers and their mode of construction prior to publication.
2. This watch was made at a time when John Arnold was constantly trying new ideas to improve his timekeepers and so could have been altered in the course of manufacture.

6 JOHN ARNOLD
1778

CHRONOMETER *Plates 5d–f, 6a–c*

Signature: Engraved on the back plate 'John Arnold London Inv^t et Fecit No 37'.

Case: Gold consular case with pump pendant to operate the half/quarter dumb repeating work. The edge of the bezel and back with an engraved decoration of leaf and flower design, maker's mark TP (possibly Thomas Primat)[1] and London hallmark for 1778. A push-piece at 8 o'clock and catch opposite. Diam. 62 mm, h. 27 mm.

Dial and hands: Flat enamel dial. The dial attached to the gilded brass dial plate by short feet and pins.

Red gold hands, seconds hand missing its tail.

Movement

Dial plate diam. 50·4 mm; front plate diam. 46·7 mm; back plate diam. 45·7 mm; frame h. 8·6 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins. Both the going and repeating trains as well as the repeating hammers pivoted between the plates. The remainder of the Stogden-type half/quarter repeating work mounted under the dial. Both plates and pillars made of gilded brass.

Going train: All the wheels are gilded, and the pinions polished to a high standard.

Fusee: Keywound and provided with maintaining power, this with a brass ratchet wheel and blued steel detent pivoted between the plates. The return spring for the maintaining detent is a short piece of steel wire pointing down from the back plate. The setting-up-work for the mainspring is between the barrel and the front plate. The polished steel click and spring are made in one piece. English stop-work.

Jewelling: All the going train pivots including the fusee are run in jewels. These are flat and practically without oil sinks, and set in brass settings held by screws in recessed holes in the plates. The escape wheel and balance jewels have endstones, the escape arbor jewel faces are not curved towards the endstones. The impulse and discharge rollers and the detent are also jewelled.

Escapement: Originally a pivoted detent escapement was fitted and the holes for this were left in place when the watch was modified to Arnold's spring detent. This could well have been done by Arnold, and with great care, because although the slot for the detent is not gilded there is no marking of the gilding round it. The detent banked by a small screw set in the back plate.

Brass escape wheel with the impulse surfaces of the teeth slightly cut where they act on the corner of the jewelled impulse pallet. Steel detent finished grey except for the polished top of the foot. The passing spring also of steel and riveted on.

Balance: The balance is made up on a solid polished steel rim and single cross-bar and known as the 'double T' type from the form of compensation. Two bimetallic strips, with a peg at each end sprung into holes in the rim, are mounted parallel to the crossbar of the balance. A steel rod is fixed at the centre of each bimetallic strip, thus making up the T-shape. Each steel rod passes freely through a hole in the rim and then has a gold weight fixed to its free end. There are steps in the rim to reduce the air resistance. Diam. 26·0 mm, h. 0·85 mm.

Changes in temperature cause the bimetallic strips to bow to a greater or lesser extent, and move the weights towards or away from the centre of the balance. The change in the moment of inertia of the balance so produced compensates for the changes in elasticity of the balance spring, and for dimensional changes.

The steel piece crossing over one of the bimetallic strips is an amplitude limiting device operated by the lower terminal curve of the balance spring. This part of the spring passes through a hole in the steel piece which is itself mounted with freedom to move towards or away from the centre of the balance. One end of the steel piece runs through a hole in a short pillar on the balance rim, the other in a slot in a brass peg set in the boss of the balance. If the balance turns clockwise the steel piece is pushed out from the centre of the balance. Should the amplitude then exceed a certain value, the outer end of the steel piece contacts a pin pointing downwards from the overhanging part of the balance cock. Since this device upsets the isochronal adjustment of the balance spring it was often removed from balances to which it was fitted.

John Arnold's famous chronometer No. 36, which was tried at Greenwich in 1779 and 1780 and gave such an outstanding performance, was fitted with a 'double T' balance (see Gould 1923, pp. 110–12).

Balance spring: Blued steel helical spring having just under 5 complete turns with a terminal curve at each end. The upper end pinned to an adjustable gilded brass overhanging stud screwed to the top plate.

Going train counts:
Great wheel (fusee) 60 teeth
Centre pinion 10 leaves, wheel 80 teeth, no crossings
Third pinion 8 leaves, wheel 48 teeth, 4 arms
Fourth pinion 8 leaves, wheel 60 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Repeating train counts:
Pinions of 6 leaves.
Wheels 48, 38, 32, 30 and 26 teeth respectively

Motion work:
Cannon pinion 4 leaves, minute wheel (square tooth form) 48 teeth
Minute pinion 36 teeth, hour wheel 36 teeth

With this watch, and possibly contemporary, is a gold chatelaine bearing the mark, MT, of an early owner, with four seals, as follows:

(i) A lozenge pattern set in an agate surround.
(ii) A carnelian seal of the arms and crest of the Edmonds family of Lidington, Rutland, Truro, Cornwall, and Winslow, Bucks.
(iii) A lava seal of the Edmonds crest and the letter E.
(iv) A carnelian seal with the Edmonds crest and the monogram RE.

Provenance: Ilbert Collection; purchased by Ilbert *c.* 1927 from Percy Webster (reg. no. CAI-1839).

Note

1. Thomas Primat's mark was registered 1777 and his address given as 3 New Compton St, Soho.

7 JOHN ARNOLD

1778 or 1779

CHRONOMETER *Plates 6d–e, 7a–b*

Signature: On the back plate 'John Arnold Inv^{t} et Fecit London N^{o} 12 there is also a '12' between the 'L' and 'o' of London. On the dial 'John Arnold, London No 12.'

Box: Octagonal mahogany box, the glazed lid with a single five-knuckle hinge, and secured by a lock. There are marks on the outside of the box indicating that at some time it has been suspended in gimbals. The glass, of a greenish colour and with a number of blemishes and air bubbles, is probably original. It is secured in a rebate by a brass bezel. The winding hole in the bottom of the box is brass lined and protected by a shutter with an eccentric key hole, but without a return spring. The brass lining tube for the hole in the wood is part of a plate fitted on the inside of the box, with a similar tube projecting upwards on the inside. This is covered by a large brass cup on the winding square. W. across the flats 160 mm, h. 84 mm.

Dial and hands: Flat enamel dial, cracked, and secured in a shallow recess on the front plate by three feet and pins.

Blued steel hands, the seconds hand screwed to a steel pipe having a blind hole and a screw head.

Movement

Front plate diam. 102·8 mm, towards the dial reduced to 100·8 mm; back plate diam. 96·1 mm; frame h. 32·7 mm.

Frame: Massive full plate construction, the back plate secured by recessed blued steel screws. No separate dial plate. The balance potance without a moulded edge to the foot. Three rectangular steel pegs project from the edge of the front plate, these fit into suitable slots in the wooden board into which the front plate is rebated. The movement is then secured by a split brass ring and three wood screws.

Fusee: Fitted with Harrison's maintaining power and the usual stop-work, the stop-piece with return spring between it and the back plate. A brass dust-excluding cup fitted on the winding square and secured with a screw. This cup fits over the tube projecting upwards from the bottom of the box. There is no date or signature on the inside of the fusee assembly. Setting-up-work is fitted on the inside of the front plate, under the end of the barrel. There is an extended square on the back plate end of the barrel arbor for setting up. The barrel is waisted on the closed end, to miss the teeth of the great wheel, and has a slight flange at the cover end. The mainspring is not tapered and is hooked by an eye to a steel hook in the barrel wall. The snailed barrel arbor is made from the solid, and without a brass boss.

Going train: The pinions and arbors of the going train are polished all over with the exception of the undercuts. The centre pinion of nine leaves is apparently original but has had to be turned on the wheel and riveted again. The fourth and escape wheels are mounted on brass collets.

Jewelling: The fourth arbor pivots run in pierced jewels, those of the escape pinion and balance staff in pierced jewels with endstones. All the jewelling is similar to ordinary nineteenth-century English jewelling and so was added or altered at a later date (see also cat. nos 33, 34 and 43).

Escapement: Probably the first marine chronometer to have Arnold's spring detent escapement. The damaged and annealed steel escape wheel held on a brass collet by two screws, and has very long slender teeth. The acting leading edges of the teeth are not formed to cycloidal curves but are almost straight and lean back, and the locking part of each tooth is near its tip. The detent is not original and is crudely made. The impulse roller is jewelled, the discharge roller was once jewelled but the jewel is now replaced by a piece of steel. The escape pinion arbor has apparently been replanted nearer the balance, the holes having been carefuly filled in and both the back plate and a potance screwed and pinned to the inside of the front plate. This potance has been raised by fixing another section of brass to the underside of its foot.

Both John Arnold's No. 11 and No. 13 marine chronometers are known. No. 11 was once a pivoted detent but has been converted to a spring detent. No. 13 has apparently always been a spring detent. There are signs that in this one the original layout was for a pivoted detent, but was altered to a spring detent at an early stage of construction.

Balance: Probably the first of John Arnold's chronometers to have a 'double T' balance. The bimetallic strips of steel and brass riveted together with rows of three rivets per row. The brass is reduced between the rows of rivets to give a corrugated appearance. A peg left standing on the steel part of the end of each strip fits into a hole in the balance rim. Wire trammels are provided to steady the rods carrying the two gold compensation nuts. There is provision of two tapped holes in the rim near the ends of the arms for timing screws, now missing. The central boss of the two-armed steel balance held with two screws on a brass collet on the staff. Diam. of rim 46·0 mm, h. 1·2 mm.

Balance spring: The remains of a blued steel helical spring pinned in a round hole in a counterpoised steel collet and to an adjustable clamp on the massive balance cock (see also cat. no. 34).

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 9 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 100 teeth, 4 arms
Escape pinion 10 leaves, wheel 12 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 15 leaves, minute pinion 20 leaves
Hour wheel 60 teeth, minute wheel 60 teeth

Provenance: Ilbert Collection; Ilbert in his inventory notebook records the acquisition of this chronometer from a Dr Stevens on 25 August 1933 or 1934, he suggests various dates for it, finally settling for 1782, and records evidence for it having once had a pivoted detent escapement. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-2067).

Exhibited: 'Pendulum to Atom'; under the auspices of The Worshipful Company of Clockmakers at Goldsmiths' Hall, London, October 1958. British Clockmakers Heritage Exhibition, Science Museum, London, May–September 1952.

Note: The chronometer is referred to by John Arnold in a letter to the Board of Longitude dated 6 March 1784. He refers to it as '... the first machine on my last construction ...'. This probably means that it is the first marine chronometer to have his spring detent escapement and double T balance.

Bibliography: Bertele 1981, p. 145.

8 JOHN ARNOLD

1780

CHRONOMETER *Plate 7c–f, 8a*

Signature: On the back plate 'John Arnold London Inv^{t} et Fecit No 21/68' On the dial 'John Arnold N°68'.

Case: Fine 22-carat gold consular, with the London hallmark for 1780 and the casemaker's marks MA over GM (Mary Aveline and Gideon Macaire, 5 Denmark St, St Giles. Mark entered with Goldsmiths' Company, 19 July 1779). Pump pendant with fluted stirrup bow and the remains of an applied rosette decoration and having a locking slide beside the pendant tube. A touch piece is fitted at 8 o'clock operating through the case to feel the dumb repeating. Diam. 73·8 mm, overall h. 31·3 mm.

Dial and hands: Flat enamel dial attached to the dial plate by three short feet and pins, the back marked '68' in red enamel. The divisions of the subsidiary seconds dial show signs of having been marked with a scriber under the enamel.

Gold hands, the minute hand held by a screw set in the boss, the seconds with a threaded hole in the boss and steel pipe with a screw head.

Movement
Dial plate diam. 63·5 mm; front plate diam. 59·4 mm; back plate diam. 58·5 mm; frame h. 10·0 mm.

Frame, going train, fusee: Similar to John Arnold No. 37 and of exceptional quality and finish. There is a wedge-shaped cut-out in the front plate for the table of the escape potance. The movement hinge, case catch and spring carried on the dial plate which clips bayonet fashion on the front plate and is secured by a single screw in the edge.

Scratched on the mainspring 'Brookes Aug 92'.

Jewelling: Similar to John Arnold No. 37, the flat jewels have small but distinct oil sinks and are of a white or pale pink colour. Near the fourth pivot in the back plate is an unused brass plate held by two screws as if for a bearing. There is a single filled hole nearby. The fourth upper jewel is a later replacement with large oil sink and curved face against the pivot shoulder.

Escapement: Originally a pivoted detent, but converted to a typical John Arnold spring detent escapement with a steel escape wheel; the underside of the wheel and the tops of the teeth polished. The wheel sunk out on the upper side. The cycloidal acting surfaces of the teeth appear to have been polished. Each is deeply grooved and scored where it has worked with the corner of the impulse roller jewel which is also worn. Both the impulse and discharge rollers are polished and jewelled. The unusually short detent is planted with its foot close to the fusee upper bearing, a screw for the fusee jewel having been moved to make room for it. The passing spring is of gold, held with a single rivet, and the locking stone of clear sapphire.

Both the drops in the escapement are fairly large.

Balance: An example of the type known as a 'double S' balance from the shape of the bimetallic compensating pieces. It is made up on a polished steel two-armed wheel, the narrow rim with inset faired portions for the mean time and compensation screws. To the underside of the central boss are screwed two blued steel brackets. Each bracket is integral with a U-shaped piece of brass and steel bimetal, the brass on the inside, to the free end of which is riveted another similar thus making up the S-shape. The free end of the second piece of bimetal carries one end of a steel rod. Each rod lies on a radial from the balance centre and carries a gold compensation screw threaded to its free end. Thin wire strips or trammels are pinned in holes in the rods and the rim to increase the rigidity of the construction. The balance once carried an amplitude limiting device operated by the balance spring similar to that of John Arnold No. 37, cat. no. 6. Only the supports for the steel rod remain. Diam. 28·5 mm, h. 1·0 mm.

Balance spring: Helical steel spring, tempered to a purple colour, of $5\frac{1}{4}$ turns and with terminal curves. Probably a later replacement slightly longer than the original as the underside of the balance cock has been turned away to make room for it. The collet is of blued steel, and both it and the gilded brass adjustable overhanging stud have square holes and corresponding pins to clamp the terminal curves.

Repeating work: Typical Stogden-type half/quarter repeating work.

The steel parts under the dial on the front plate were once highly polished, many on both sides, but are now badly rusted.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms

Motion work:
Cannon pinion 6 pins, brass minute pinion 48 teeth
Hour wheel 48 teeth, minute wheel 72 teeth

Repeating train:
Great wheel 56 teeth
Second wheel 38 teeth, first pinion 8 leaves
Third wheel 34 teeth, second pinion 6 leaves
Fourth wheel 30 teeth, third pinion 6 leaves
Fifth wheel 25 teeth, fourth pinion 6 leaves
Fifth pinion 6 leaves

Provenance: Some of the early history of this watch is known. It first belonged to a Mr Edward Everard, a wine merchant of Lynn, who kept a careful note of its going as compared with a regulator. He apparently did a good deal of travelling and subjected the watch to some rough treatment. However it went so well that when he sent an account of its rate to John Arnold, the latter published this in a pamphlet in 1791 entitled *Certificates and Circumstances relative to the going of Mr Arnold's Chronometers.* In the same phamphlet is reproduced the official rate of the famous No. 36 tested for thirteen months at the Royal Observatory, Greenwich in 1779 and 1780. Ilbert Collection; purchased by Ilbert from Elkington in 1933 (reg. no. CAI-301).

II.ii (cat. nos 9–31)

THE USE OF THE PIVOTED DETENT BY OTHER MAKERS

In this section are included all the chronometers in the collection with pivoted detent escapements made following the work of the pioneers.

The twenty-three chronometers in this section can be divided as follows:
English: cat. nos 9, 14, 15, 21, 23
French: cat. nos 10, 11, 13, 16, 17, 18, 20
Swiss or French: cat. nos 12, 19
Swiss: cat. nos 24, 25, 26, 27, 28, 29, 30, 31
Danish: cat. no. 22.

Of the total number, somewhat surprisingly, thirteen have going barrels, one being a marine chronometer by John Roger Arnold, namely cat. no. 14. The others with going barrels are cat. nos 12, 17, 18, 19, 20, 21, 22, 24, 26, 29, 30, and 31. The other chronometers have fusees, namely cat. nos 9, 10, 11, 13, 15, 16, 23, 25, 27, 28.

The proportion of English pivoted detent chronometers in this section is not indicative of the overall picture since the use of the pivoted detent was largely confined to the continent.

In their early days, both Arnold and Earnshaw used the pivoted detent, and both came to the conclusion that the spring detent would be better. No pivoted detent by Earnshaw has survived, but several by John Arnold are known, including two in the collection: cat. nos 4 and 5. Both makers complained of the effects of thickening of the oil at the detent pivot holes, but a careful examination of the two Arnold escapements reveals that they would have had other problems as well. The locking jewels do not have 'draw', but have locking surfaces lying on an arc, struck from the pallet centre. Both detents are also comparatively heavy so that there would be a high risk of them bouncing against their stops. The short leaf return springs are rather fierce in their action in order to offset these two effects and would each have had to be oiled at their point of application. One has only to compare these with later detents to see what improvements could be made; note especially the marine chronometers by Louis Berthoud and Henri Motel and the pocket chronometers by Swiss makers. Following the success of Arnold and Earnshaw with spring detent escapements the pivoted detent was little used in England, and was regarded, unjustifiably, with disfavour.

The origins of the use of the pivoted detent escapement on the continent, especially by French chronometer makers, undoubtedly go back to the work of Pierre le Roy and Ferdinand Berthoud (see Introduction). French and Swiss makers who were able to overcome the various problems encountered by the English pioneers achieved results comparable with their English contemporaries who used the spring detent. If both are well proportioned, carefully made and adjusted, there appears to be little to choose between the two types of escapement for either marine or pocket use.

Continental makers argued that a pivoted detent is stronger and less liable to accidental breakage when being handled than a spring detent. A pivoted detent can be accurately poised, which is a distinct advantage for pocket use, but great care must be taken to keep the inertia to a minimum to avoid 'bouncing on the stop', so the detent should be kept as short as possible. This introduces the disadvantage of a rather large unlocking arc which, however, is mitigated by the more even action of a spiral return spring, as compared with that given by the straight spring of the spring detent (see Plate 26e.)

9 JOSIAH EMERY
1778

CHRONOMETER *Plates 8b–e, 9a–b*

Signature: On the back plate 'Josiah Emery Charing Cross London 781'. On the dust cover 'Jos^{h} Emery Charing Cross, London, 781'. On the dial 'Josiah Emery London'.

Case: Gold consular case with the London hallmark for 1778 and an indistinct maker's mark possibily 'IM'. The case catch in the band of the case operates catches for both bezel and back. The book hinge has seven knuckles. Diam. 50·2 mm, h. over glass 24·0 mm.

The following inscription has been engraved on the inside of the back:

> This CHRONOMETER, worn by the 2 & 3 DUKES – of – NORTHUMBERLAND was presented by ALGERNON the 4th DUKE to WILLIAM LAWS of PRUDHOE CASTLE, as a Mark of Respect and in remembrance of nearly 40 Years Service as BAILIFF & COMMISSIONER to three successive DUKES. April 1847.

Dial and hands: Enamel dial with curved edge, fixed to the dial plate by two short feet and pins.

Gold minute and hour hands, blued steel seconds hand.

Movement
Dial plate diam. 41·0 mm; front plate diam. 38·5 mm; back plate diam. 37·4 mm; frame h. 10·0 mm.

Frame: Similar to cat. no. 2 (compare the illustrations); note the shape of the bridge on the front plate carrying the fourth and escape bearings with a piece to protect the fourth wheel. The front plate has been recessed to allow room for the dial feet and pins in the thin dial plate. There is no provision for a movement hinge on the dial plate, the movement is retained in its case by two polished screws in the band of the case going into the edge of the dial plate. There is no evidence of any provision for a case catch and spring, but a balance stop mechanism (now missing), was operated by a push between 4 o'clock and 5 o'clock. The middle of the case has been prepared for a movement hinge, a piece of tube having been soldered in place but never used. The dial plate fixed to the front plate by three feet and pins.

Fusee: Keywind fusee with normal stop-work and maintaining power. The maintaining power ratchet wheel of brass. The shape of the foot of the maintaining detent return spring similar to that of cat. no. 2. The setting-up-work on the inside of the front plate, the click and spring made from the solid, the spring tail now broken off. Compare with John Arnold cat. no. 5 and Emery cat. no. 119. The top of the barrel flanged and the lower end of the barrel reduced to clear the centre pinion. The great wheel most unusually the same size as the brass maintaining wheel.

Going train: Similar to cat. no. 2, the great wheel with the unusual number of 51 teeth. The number of beats per hour is also remarkable: 18,102 and six sevenths.

Jewelling: All the pivots of the going train run in pierced jewels made from clear sapphire. Only the fourth upper has an obvious oil reservoir, the remainder are without. The pivots of the escape pinion arbor, the detent arbor and the balance staff run in pierced jewels with endstones. The endstones in the plates are set blind in brass plates, retained by screws. Those in the balance and detent potances are set in wedge-shaped pieces of brass. There is the correct gap in each case between the curved top of the pierced jewel and the bottom of the corresponding endstone.

Escapement: Pivoted detent escapement with polished steel escape wheel, the detent made in two parts, one a jewelled arm for locking the escape wheel and the other a triangular-shaped piece carrying the passing spring, made of blued steel. The lower pivot of the detent supported by a curious potance with a broad and engraved edge. The grained steel impulse roller with inset impulse jewel, the impulse face leaning slightly towards a radial from the roller centre to the tip. Three holes drilled in the impulse roller opposite the impulse jewel for poising. The discharge roller jewelled in the usual way. The return spring for the detent a leaf spring set in a separate block and with a screw to adjust the tension. The tail of the jewelled arm of the detent banking against another adjustable screw set in the detent potance.

Balance: Gilded brass three-armed balance with various notches filed in the underside of the rim for poising, no screws or weights. Diameter of rim 19·9 mm, h. 0·94 mm.

Balance spring: Blued steel helical balance spring of 6 turns without terminal curves. The lower end clamped to an elaborate poised brass collet on the balance staff, the upper end clamped to a stud overhanging the balance and screwed in a slot in the compensation framework. The stud consists of two pieces, one of gilded brass fixed to the top plate and the other a wedge-shaped steel piece running in a matching slot in the first piece.

Thermal compensation: One end of a steel index on the balance bridge is acted on by a coiled bimetallic strip. At the other end of the index, brass pins embrace the upper coil of the balance spring. The index is retained by a blued steel plate and two screws. The coiled bimetallic strip is screwed inside a bridge, itself screwed to a framework mounted on the back plate, with a toothed sector engaged by a steel pinion with squared arbor. This arbor receives the regulation index whose boss passes through the dust cover on which is marked the scale against which the tail of the index registers for mean time regulation. This whole assembly with its engraved retaining bridge held by four screws on the back plate. It appears to have undergone a certain amount of modification as certain holes are now unfilled.

Going-train counts:
Great wheel (fusee) 51 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 66 teeth, 4 arms
Escape pinion 7 leaves, wheel 16 teeth, 4 arms
Beats per hour: 18,102 6/7

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

The cannon pinion was retained by a pin through the end of the centre arbor which is now broken back to the hole.

Provenance: as the inscription in the case. Subsequently part of the collection of S.E. Prestige; purchased from the executors of the will of S.E. Prestige's widow (reg. no. 1969, 3-3,1).

10 LOUIS BERTHOUD

c. 1797 from the hallmark, but probably earlier[1]

MARINE CHRONOMETER I-DAY *Plates 9c–f, 10a–b*

Signature: on the back plate 'Par Louis Berthoud No 49'. On the dial 'No 49 L^{s} Berthoud'.[2] Around the edge of the dial ring: 'N° 49 Construite Par Louis Berthoud)'.

Box: The movement fitting with bayonet catch into an engine-turned silver box with the French Corporation of Paris hallmark for 1797, a horse's head in a cartouche (see Tardy, *Poinçons*, 5th edn, p. 112) and the maker's mark 'J L J' and a bird in flight in a lozenge. The top of the box has a raised glass, there is a keyhole in the bottom and a cover over this. This silver box fits in a heavily weighted brass cradle, lined on the inside with blue velvet, gimballed in a mahogany box. There is a lock for the gimbal ring and another for the box. The winding key fits in a tube standing on the bottom of the box. There is a sliding cover over a circular aperture in the lid, no carrying handles. Silver box diam. 68·5 mm, h. 31·5 mm. Mahogany box, base 129 mm square, sides 123 mm square, overall h. 86·8 mm.

Dial and hands: Enamel regulator type of dial attached in a recess in a dial ring on the front plate by two feet passing through the front plate and pinned. The back of the dial signed in enamel 'lucard'. (See cat. nos 11, 120, 121, 169.)

Blued steel hands.

Movement

Engraved on the dial side of the front plate 'No 49'. and scratched on the opposite side 'R.C. 1882 Montevideo'.

Dial ring diam. 65·3 mm; front plate diam. 61·7 mm; back plate diam. 61·4 mm; frame ht. 11·9 mm

Frame: Full plate construction with four turned pillars held with brass nuts to the front plate and blued steel nuts and polished steel washers to the back plate. The escapement pivoted between the back plate and potances screwed to the back plate. All the brass parts are finely frosted and gilded. Each pillar has a central steel shaft passing through it, threaded at each end for a nut. The dial ring held by a pin and four blued steel screws. There was once a secret catch and spring on the dial side of the front plate to lock the movement in the silver box, operated by applying a pin through a small hole in the edge of the box (see cat. no. 13).

Fusee: Fitted with Harrison's maintaining power with a steel ratchet wheel and English stop-work. The setting-up-work is on the dial side of the front plate. The fusee arbor is carried in separate bearings screwed to the frame, there is a dust-excluding silver cap on the squared part of the arbor inside a tube with a foot screwed to the bearing. The barrel arbor is solid and not snailed, the mainspring is attached by hook and eye at both ends. Originally there was a bride between the barrel cover and bottom to hold the last coil of spring against the barrel wall.

Going train: Very well made and finished light train with high counts, the centre and fourth wheels held by screws. The pinions and arbors polished on every surface including the undercuts. The wheels polished flat and not gilded.

Jewelling: The pivots of the centre, third, fourth and escape wheel balance arbors in pierced jewels, either clear or pale pink. The train jewels in the back plate and the third in the front plate have polished steel plates to take the end thrust. Each of the jewels mentioned has an oil sink on both sides and there is no provision for oil retention between the end plate and the jewel. The balance jewelling has small endstones at each end with a diamond at the back. The other escapement jewelling has steel endplates like the going train. The detent pivots running in brass holes.

Escapement: Pivoted detent escapement, the brass escape wheel held with screws on a brass collet, and with the rim and arms sunk below the teeth on the side towards the back plate. The very thin and light detent, riveted to a polished steel collet on its arbor, has an integral steel locking surface standing at right angles to one side and a passing spring held with a screw and steady pin and banking against a pin on the end of the detent towards the balance. The detent is returned by a light spring, with adjustable tension by an eccentric brass plug in the back plate, acting on a brass collet on the detent arbor. The tail of the detent banks against a flat jewel set in a bracket secured to the underside of the backplate. The polished steel impulse roller is mounted eccentrically so that the rounded end of the radical impulse surface is further from the balance axis than the rest of the circumference. The detent is unlocked by a small steel roller pivoted in holes in a brass frame on the balance staff.

Balance: Bimetallic three-arm balance with brass segment weights fixed by a small screw on the outside. Each brass weight has a larger steel screw on the outside to lock another smaller, set in the end to make fine adjustments to the compensation. A brass block is clamped over the rim at the end of each arm by a small brass screw on the inside, and carries a steel timing screw on the outside. The balance is held by three screws on a brass collet. Diam. of rim 23·3 mm, h. 1·3 mm.

Balance spring: Blued steel conical spring of $6\frac{1}{4}$ turns with concentric clamping at each end and without terminal curves. The stud clamp has 3 levelling screws and a spring to hold it during levelling.

Going-train counts:
Great wheel (fusee) 86 teeth, $7\frac{3}{4}$ turns of groove
Centre pinion 24 leaves, wheel 128 teeth, 4 arms
Third pinion 16 leaves, wheel 120 teeth, 4 arms
Fourth pinion 16 leaves, wheel 100 teeth, 4 arms
Escape pinion 8 leaves, wheel 12 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; Ilbert records the acquisition of this chronometer from Webster about 1930. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1928).

Notes

1. A similar chronometer (cat. no. 38) is known to have been completed in 1795. There appears to be a gap in the French hallmarking system between 1789 and 1797, none being recorded by Tardy (*Les Poinçons de Garantie Internationaux Pour L'Or*, Paris, 1942). It therefore seems likely that the date of manufacture of this chronometer is earlier than that shown but must, however, be within the period 1793–7.

2. Pierre Louis Berthoud (1754–1813) was born at Plancement in Switzerland and died at Chaillot. He was the nephew of, and instructed by, Ferdinand Berthoud and carried on the latter's tradition and work; he is reputed to have constructed about 150 chronometers.

Bibliography: Bertele 1981, p. 170.

II HILAIRE BASSEREAU

1804

CHRONOMETER MOVEMENT *Plates 10c–e, 11a–b*

Signature: On the dial 'Hilaire Bassereau Palais Royal'. On the cuvette '1/1804 Hil$^{\underline{\text{re}}}$ Bassereau No 316'.

Dial and hands: Slightly curved enamel dial, the edge gilded, the backing blue, secured by two feet and screws in the edge of the movement. Dial signed on the back 'Lucard' (see cat. nos 10, 120, 121, 169). Arabic hour numerals, no seconds.

Blued steel moon hands, set from the front by a square on the cannon pinion.

Movement
Movement drum diam. 50 mm inside case; rear flange diam. 51·3 mm; front plate diam. 49·80 mm; frame h. 7.40 mm.

Frame: Typical Lepine construction with his type of balance and barrel cocks. The cocks and barrel cap decorated with engraving. The main plate recessed under the dial. Blued steel screws, brass parts gilded. The movement fitting into a drum and retained by radial screws, and having a cuvette hinged to the drum, these parts also of gilded brass.

Fusee: Keywind fusee, winding through the dial. Harrison's maintaining power with a steel ratchet wheel. Five-turn Geneva-type stop-work, and barrel setting-up-work, lodged on the main plate under the dial. Barrel flanged at both ends, incorporating a brace to assist the hooking of the outer end of the spring. The fusee originally prepared for stop-work operated by the chain at the smaller end, the slot filled.

Going train: Conventional layout and construction, the brass wheels polished and riveted to their pinions.

Jewelling: Only the balance pivots in pierced jewels and with endstones. The working surfaces of the escapement left unjewelled.

Escapement: Pivoted detent escapement. The brass escape wheel mounted on a brass collet on the pinion arbor, and having very short teeth leaning slightly forwards. Steel triangular impulse pallet, its acting surface leaning away from a radial to the tip. The discharge roller a short steel tube adjusted tight on the balance staff, carrying an integral discharge piece lying between itself and the impulse pallet. The steel detent with integral locking surface, carrying a pin set in the nose to bank the passing spring. The passing spring also of steel, carried on the underside of the detent, its foot secured by a single screw. The detent banked against a brass pin set in the plate and returned by a straight spring.

Balance: Plain gilded brass three-armed balance without compensation, the crossings marked with dots on the underside. Diam. 18·6 mm, h. 1·1 mm.

Balance spring: Blued steel spiral spring of just over $9\frac{1}{2}$ turns pinned to a brass collet and stud, and with an index on the cock, the index having a modern Swiss type pin and boot.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 10 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 64 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 17,554·285

Motion work:
Cannon pinion 12 leaves, minute pinion 8 leaves
Hour wheel 40 teeth, minute wheel 30 teeth

The minute wheel and pinion are an incorrect replacement; probable counts would be 36 for the wheel and 10 for the pinion.

Provenance: Ilbert Collection; purchased by Ilbert in the Boulevard Raspail in Paris in 1934 (reg. no. CAI–1587).

12 UNKNOWN, possibly Swiss
Early 19th century

CHRONOMETER MOVEMENT *Plate 11c–d*

Dial and hands: None.

Movement details
Dial ring diam. 55·0 mm; front plate diam. 51·2 mm; back plate diam. 51·2 mm; frame th. 6·2 mm.

Frame: Full plate construction with a dial ring held by four screws under the dial. Four turned pillars, the back plate held by pins. Engraved bridge cock and barrel bridge. The edge of the dial ring also engraved. All the brass parts gilded.

Going barrel: Of very large diameter extending beyond the centre of the frame. The ratchet and click on the barrel bridge. No stop-work. The mainspring hooked to the barrel wall by hook and eye, and with a brace. The barrel arbor with a steel centre and brass boss.

Going train: An early example of an offset train in which the centre wheel is displaced to leave room for a larger than normal barrel. No provision for a seconds hand.

Escapement: A crudely made pivoted detent without jewelling. The impulse plane leaning slightly towards a radial to the tip. Two steel discharge rollers, one above and one below the impulse roller, only the lower one now used to unlock the detent. The detent backed against a dog screw near the point of pivoting, and returned by a single leaf spring. Diam. 23·0 mm, h. 0·75 mm.

Balance: Plain three-armed brass balance, flat spiral spring of blued steel having $6\frac{3}{4}$ turns, without any thermal compensation. Rack and pinion gearing for mean time adjustment with triangular-shaped teeth. A and R marked on either side of the regulator.

Amplitude limiting device: The balance spring is below the balance. Above the balance a loose finger piece is adjusted on the balance staff and retained by a brass collar. Its movement is limited by a steel pin set in the balance boss. The loose piece is able to contact another pin set in the balance bridge and pointing down into its path. Such a device, although very ingenious and simple, introduces a variable friction during the motion of the balance.

Going-train counts:
Barrel 84 teeth.
Centre pinion 12 leaves, wheel 64 teeth, no crossings but 5 holes for lightening purposes
Third pinion 8 leaves, wheel 50 teeth, 4 arms
Fourth pinion 8 leaves, wheel 50 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms

Motion work: Mostly missing, a fixed wheel at the centre of 40 teeth remains. The offset centre arbor is hollow and carries the hand-setting arbor with a pinion of 8 leaves. This pinion must have driven some kind of epicyclic motion work now missing.

Provenance: Ilbert Collection; purchased by Ilbert from Lebrassier in 1938 (reg. no. CAI–1827).

13 LOUIS BERTHOUD
1811

MARINE CHRONOMETER *Plates 11e–f, 12a–b*

Signature: On the back plate 'Construite par Louis Berthoud No 127.' On the dial 'Louis Berthoud Hor$^{\underline{\text{ger}}}$ de la Marine No 127 bis'[1] and DEPÔT DE LA MARINE written on top of the glaze. Around the edge of the dial ring: 'No 127 Construite par Louis Berthoud'.

Box: The movement contained in a brass drum in which it is held by a bayonet fastening and secret catch operated by pushing with a pin through a very small hole in the side. This arrangement also used by Motel. The threaded bezel, engraved DÉPÔT G$^{\underline{\text{AL}}}$ DE LA MARINE, holds another similar unthreaded bezel with a raised glass, and similarly signed but without the G$^{\underline{\text{AL}}}$. The bottom is a push fit, secured by two screws in the edge and engraved 'No 127 Département de la Marine 9$^{\text{bre}}$ 1811'. In order to insert the key for winding, two overlapping escutcheon plates must be rotated until their holes coincide with a third in the bottom. The brass drum fits into a weighted brass cradle with a gimbal ring pivoted in a mahogany box similar to, but larger than, cat. no. 10. Inscribed on a diamond-shaped brass insert on the front of the top 'No 127 BIS'. There is a tipsy key in one corner of the box.[2]

Dimensions: Brass drum, 82·9 mm diam, 43·5 mm h.; Mahogany box: base 140 mm square; sides 136 mm square; overall h. 114 mm.

Dial and hands: Enamel regulator type of dial attached in a recess in the dial ring on the front plate by two feet passing through the front plate and pins.

Blued steel moon hands.

Movement
Dial ring diam. 80·1 mm; front plate diam. 75·1 mm ; back plate diam. 74·6 mm; frame h. 17·0 mm.

Frame: Similar to L. Berthoud, cat. no. 10, but larger. The brass parts smooth but not polished or gilded. The dial plate held by a small screw and four larger screws. If the small screw is removed and the others slackened, the dial ring can be rotated and removed.

Fusee: Similar to L. Berthoud, cat. no. 10. The bride is still in place in the barrel.

Going train: Similar to L. Berthoud, cat. no. 10.

Jewelling: The pivots of the centre arbor and the third in the back plate, in detachable bushes held with screws. The third arbor in the front plate, both fourth arbor pivots and those of the escape pinion and balance staff in pierced jewels. Steel end-thrust plates, highly polished and held with a single screw, are fitted over all bearings except the centre and fourth at the front. Only the balance staff pivots run between endstones.

Escapement: Similar to L. Berthoud, cat. no. 10. The brass escape wheel is sunk out on both sides and is exceptionally light. There is a brass stop-piece which can be swung into the path of the escape wheel teeth. The detent is banked by its tail resting against a brass peg set in the back plate, and there is a small hole in the locking surface at the height of locking.

Balance: Bimetallic four-armed balance with brass segment weights, the free ends of the rim sections finely graduated to help in positioning the weights. Each weight is held by a small brass screw from the outside. There are two other screws in the outside of the weight, a fixed brass screw towards the fixed end of the rim section and a larger steel screw towards the free end. There is a small brass clamping screw for each steel screw set in the end of the weight. The steel screws are for poising and bringing to time. The balance is held by two screws on a brass collet. Diam. of rim 27·0 mm; h. 2.1 mm.

Balance spring: Blued steel helical spring of $9\frac{3}{4}$ turns without terminal curves, clamped concentrically at full turns to both collet and stud. The stud has 3 levelling screws and a central fixing screw.

Going-train counts:
Great wheel (fusee) 108 teeth, 8 turns of groove
Centre pinion 26 leaves, wheel 112 teeth, 4 arms
3rd pinion 14 leaves, wheel 105 teeth, 4 arms
4th pinion 14 leaves, wheel 120 teeth, 4 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 21,600

Motion work:
Centre pinion 18 leaves, clamped to the arbor by a screw in a spring collar, minute pinion 16 leaves
Hour wheel 64 teeth, minute wheel 54 teeth

Provenance: Ilbert Collection; Ilbert in his inventory notebook records the acquisition of this chronometer from the Royal Observatory, Greenwich, on 22 November 1930. He also mentions that no. 108 is dated 1811. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1941).

Notes

1. The 'bis' on the dial and on the brass insert indicate that this was the second of two chronometers with the same number.
2. Inside the box lid there is a label: 'Les Huiles ont été mises en Janvier 1919 par E. Boudeaud 40, Rue Pergolèsi Paris Anc$^{\text{ne}}$ Maison Winnerl and Callier. 127 bis'.

Bibliography: Bertele 1981, p. 176.

14 JOHN R. ARNOLD
1813

MARINE CHRONOMETER 1-DAY *Plate 12c–d*

Signature: On the back plate 'Jn° R. Arnold London No 413 Inv$^{\text{t}}$ et Fecit'. On the dial 'Arnold London 413'.

Box: Square mahogany box with a glazed top missing its lid, fitted with handles, a lock and an ivory inset disc engraved with the British Government Property mark, 'Arnold' and '413'. The side sections are dovetailed together and around the edge of the top of the bottom part of the box is glued a strip of green baize. The movement contained in a brass bowl in gimbals in the box, with a bezel having a bayonet fixing on three pegs and with a domed glass. In a deep recess in the bottom of the brass drum is fitted a spring-loaded escutcheon plate with eccentric hole for the key. An ingenious lock is fitted to the gimbal ring consisting of a brass arm pivoted in the middle on a shoulder screw on the top of the wide gimbal ring. In the locked position one end fits into a slot in a piece screwed to the brass bowl and the other end under the head of a locking screw carried on a plate in the corner of the box. In the recessed position the arm pivots until it lies along the gimbal ring. 150 mm square, h. 141 mm, excl. missing lid.

Dial and hands: Engraved, silvered brass dial, the engraving filled with black wax, attached to the front plate by three short pillars and pins. The pillars are turned with shoulders to leave a gap between the front plate and the underneath of the dial for the motion work.

Blued steel hands, all of flat section, the seconds hand screwed to its pipe.

Movement
Dial diam. 76·4 mm; front plate diam. 64·4 mm; back plate diam. 64·5 mm; frame h. 17·3 mm.

Frame: Full plate construction with a detachable barrel bridge and four turned pillars, the back plate retained by pins. The balance staff lower pivot is planted in the front plate instead of in the usual potance. The front plate is not pierced for the third wheel although the third and fourth arbor lower pivots are carried in a separate bridge.

Going barrel: Fitted with four-turn stop-work on the cover, the finger piece pivoting in the barrel bridge. The snap-on cover provided with a brass block fitting into any one of three slots in the top of the barrel to prevent the cover turning. The winding ratchet, click and spring fitted on the barrel bridge, and resembling J. R. Arnold's setting-up-work for a barrel with fusee. The inner end of the mainspring hooked to the solid snailed barrel arbor, the outer end with a solid block in a slot in the barrel wall, and signed 'R. Clark Dec^{r} 1813'. The barrel fixed to the great wheel in a turned sink by three recessed screws from the outside of the great wheel.

Going train: The wheels riveted to their pinions, the latter and their arbors well finished and polished. The escape pinion is missing.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones, a diamond endstone in a brass ring in the balance cock. The jewelling is of the usual nineteenth-century English type.

Escapement: An unusual form of pivoted detent, probably experimental. Unfortunately the escape wheel is missing but it must have worked as in an Earnshaw escapement with the detent in compression. The steel impulse roller carries a brass semicircular frame screwed to its upper surface in which is set a ruby pin to receive the impulse. It can be moved towards or away from the balance axis by a screw in the brass frame bearing on the balance staff. The ruby pin is carried between brass shrouds arranged in the gap in the steel roller normally occupied by the impulse jewel. The teeth of the escape wheel must have had nearly pointed teeth leaning slightly towards a radial to their tips. The light steel detent, mounted on a brass collet, is pivoted in the frame. It has a narrow flat locking stone projecting towards the back plate, indicating that it locked the teeth by their tips as in an Earnshaw escapement. The tail banks against a screw set in a brass piece screwed and pinned to the underside of the back plate. The gold passing spring is held by a single rivet. A spiral return spring for the detent is colleted to a brass block on the arbor and to a stud on a rotatable index on the inside of the front plate. The index consists of a split ring and boss, the latter held by two screws, and with a tail which can be moved to alter the set up of the spiral spring.

Balance: Later two-armed bimetallic balance with brass screws and quarter nuts. From the height available under the overhanging part of the balance cock it seems likely that one of Arnold's flat bimetallic balances with upstanding rods carrying compensation nuts was originally fitted. Diam. of rim 22·7 mm, h. 3·0 mm.

Balance spring: Blued steel open coiled helical spring of $8\frac{1}{8}$ turns with terminal curves. A split brass collet on the balance staff and a brass diamond-shaped stud with lateral adjusting screw. Both collet and stud have round holes and D-shaped pins to clamp the spring.

Going-train counts:
Great wheel 80 teeth
Centre pinion 8 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
The missing Escape pinion certainly 7 leaves and the wheel 12 teeth, as confirmed by the period of the balance and spring system
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

Provenance: According to the Chronometer Ledgers preserved at the National Maritime Museum, Greenwich, No. 413's service with the Royal Navy was as follows:

7th Nov. 1823 *Superb* Capt^{n} T. Hains
25th April 1826 *Dryad* Capt^{n} Hon. R. Rodney
19th July 1830 *Talbot* Capt^{n} R. Dickinson
12th Jan. 1837 *Dido* Capt^{n} L. Davies
14th Nov. 1841 *Serpent*
30th Aug. 1847 H.M.S. *Prometheus*
25th Aug. 1852 H.M.S. *Trident*
5th Oct. 1857 *Avon*
15th May 1861 H.M.S. *Formidable*
Nov. 1861 Given to Mr C. Frodsham with £28 in exchange for C. Frodsham No. 3156

Subsequently Ilbert Collection (reg. no. CAI–1938). Presented by Mr Gilbert Edgar C.B.E. in 1958.

15 JAMES FERGUSON
1820

CHRONOMETER *Plates 12e–f, 13a–b*

Signature: On the back plate 'JAMES FERGUSON COLE Nº SX LONDON. Inv^{t} et Fecit London'. On a silver plate fixed to the foot of the balance cock PATENT.

Case: Open face heavy gold case with the London hallmark for 1820 and an indistinct maker's mark, probably HJ (Henry Jackson). The front, glazed dome and back hinged to the reeded middle. No case springs. Pendant stamped IHG (John Henry Green) and the mark for 18-carat gold. Diam. 60·3 mm, th. 23·2 mm.

Dial and hands: Enamel dial attached to the dial plate with three feet and pins. Dial inscribed COLE LONDON.

Blued steel moon hands, the seconds riveted to its pipe.

Movement

Dial plate diam. 53·0 mm; front plate diam. 50·6 mm; front plate th. 1·27 mm; back plate diam 47·7 mm; frame ht. 7·6 mm.

The movement design is a curious mixture of full plate and Lepine. A bridge secured by three screws to turned pillars supports the barrel, fusee, centre wheel and balance cock, the balance being mounted above plate level. There is a detachable barrel bridge. The third, fourth and escape wheels supported by cocks, the top surface of these being engraved. The pivoted detent is located between the bridge and a potance, the potance foot being much extended to act as a chain guard. The balance cock appears to have been moved during the course of manufacture. The dial plate is pinned to the front plate and carried three dog screws for fixing in the case and a peg for positioning the movement. The frame and dial plate gilded, the screws blued. The dust pipe around the winding square also with an engraved foot.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel of steel. The setting-up-work of polished steel with a click spring on the bridge that forms the back plate.

Going train: Not unusual, the brass wheels gilded.

Jewelling: The pivots of the third and fourth arbors run in pierced jewels in brass settings held by screws. The pivots of the escapement in pierced jewels with endstones, similarly set.

Escapement: Pivoted detent escapement, the four-armed steel escape wheel recessed and with teeth and bottom of the wheel highly polished, and teeth with exaggerated forward rake. Cumbersome blued-steel S-shaped detent, not poised, banking by the tip of the triangular locking stone against an adjustable peg set in a screw in the back plate. The leaf return spring fixed with a brass peg in a hole in the detent cock and acting on the detent near the locking stone. As the detent moves the end of the leaf spring slides against it. The passing spring mounted in a block on the end of the detent and pointing back along the part of the detent with a banking pin set in it. The discharge roller normal, the impulse roller made up of a polished steel roller with the impulse pallet set in it with slight forward rake, screwed inside a flanged disc to provide safety action.

The escapement is remarkable for its bad design, the flanged disc appears to be an afterthought added when it was discovered that there was inadequate safety action. On the return swing of the balance the detent can be seen to wobble during the passing action due to the dangerous and defective method of banking. It would be necessary to oil the detent return spring at its point of action. The escapement is also disproportionately large compared with the balance.

Balance: Brass and steel bimetallic balance with gold quarter and compensation screws. Diam. of rim 19·8 mm, h. 1·43 mm.

Balance spring: Blued steel spiral spring of 12 turns with a short overcoil, pinned to an elaborate stud overhanging the balance and screwed to the third cock, spring probably not original. Brass collet. An elaborate and complicated micrometer adjustment for the index, mounted on the top of the balance cock, to which presumably the patent must refer. Despite appearance there is no shock protection for the balance staff upper pivot incorporated in this device, although it would appear that this was the original intention.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Webster in 1934 (reg. no. CAI-1726).

Note: J. F. Cole was granted patent No. 4530 on 27 January 1821. This refers to various improvements in the design of a pivoted detent escapement, and a compensation curb added to a watch index, including a fine adjustment for mean time. The watch, it appears, is effectively a prototype.

Bibliography: Clutton and Daniels 1965, p. 72.

16 HENRI MOTEL

c. 1826

MARINE CHRONOMETER *Plates 13c–f, 14a–e*

Signature: On the dial MOTEL N° 44. On the edge of the dial ring H$^{\underline{\text{RI}}}$ MOTEL H$^{\text{GER}}$ DE LA MARINE R$^{\underline{\text{LE}}}$.

Box: The movement fitting with a bayonet and catch, in a heavy brass canister, the bottom glazed, the dial protected by a glazed bezel fitting on the outside of the canister where it is held by three screws. On the wide flange of the bezel at III o'clock there is a sliding shutter over the winding hole. The canister fits in a brass cradle lined with green velvet, gimballed in a well-made dark mahogany box. A brass knob in the bottom right-hand corner of the box operates on a bar pivoted on the bottom of the box. This acts on the bottom of the hemispherical brass weight on the underside of the cradle and locks the gimbal assembly. A small well-made tipsy key numbered 161 fits in the other right-hand corner (see Plate 16i). There is the usual lock for the box, a sliding panel with diamond-shaped brass piece inset engraved N 44M with brass ring to retain the glass (now missing) over a circular aperture in the lid and an ivory disc set in the front of the top of the box. This last is engraved 44 MOTEL * L. LECOCQ, it has an integral threaded portion passing through the wood panel and held by an ivory nut at the back. There are no carrying handles. Base 165 mm square; sides 160 mm square; h. 137 mm square.

A label inside the lid reads:

L. LEROY & C^{ie}
HOROLOGER DE LA MARINE
7, BOULEVARD de la Madelaine
PARIS.
Date des Huiles
44
Juiee 1917

Dial and hands: Flat engraved, silvered brass dial with recessed subsidiary seconds, the engraving filled with black wax, the surface of the dial frosted. Two round dial feet, soft soldered on, pass through holes in the front plate and have screws passing into tapped holes.

Blued steel hands.

Movement

Dial ring diam. 80·4 mm; front plate diam. 75·1 mm; back plate diam. 73·8 mm; frame h. 18·2 mm.

Frame: Full plate construction with four finely grained steel pillars attached to the front plate by brass nuts and to the back plate by polished steel nuts and blued steel washers. The dial ring is recessed for both the front plate and the dial, and is held by two shouldered screws on the front plate under the dial. The escapement is mounted on a separate plate on four short steel pillars attached to the inside of the front plate. The bridge over the balance also has four steel pillars, two hollow for the fixing screws. The layout and construction is similar to that of Louis Berthoud's, including the case catch. There are holes in the back plate to view the great wheel-centre pinion and centre wheel-third pinion gearing.

Fusee: Fitted with the English type of stop-work, the return spring for the stop piece is fitted on the outside of the back plate and acts through a hole in the plate. The Harrison maintaining power has a steel ratchet wheel. The setting-up-work is on the dial side of the front plate. The barrel has a wide flange on the cover end, the arbor is solid and unsnailed, the mainspring is hooked with an eye at both ends and there is a bride which is signed 'Vincent Juillet 1826'. The great wheel assembly is held on the fusee by a plate and two screws passing into the central boss of the fusee iron. The steel ratchet wheel is cut on the edge of the fusee iron.

Going train: Very well made and finished, the pinions and arbors black polished, the centre wheel held with two screws passing into the pinion, the fourth wheel similarly held to a brass collet. The wheels decorated with patterns of stripes.

Jewelling: The third arbor pivot and those of the fourth, escape pinion and balance staff in pierced jewels. With the exception of the fourth front bearing, endstones are provided for all the jewelled bearings including a diamond on the balance bridge. Where possible steel end plates are fitted to all the going-train bearings, the bearings themselves being detachable brass bushes.

Escapement: Pivoted detent escapement showing a close resemblance to those of Louis Berthoud. The brass escape wheel is recessed on both sides leaving only the tips of the teeth the full height. Each tooth is pierced with a small hole just below the tip, and the wheel is mounted on a steel collet on the arbor. The locking stone jewel is of rectangular section where it is set in the detent, and has one long and one short side rounded on the acting portion. The tail of the detent banks against a disc of jewel mounted in a brass bracket. The various cocks on the detachable escapement platform have steel steady pins. The impulse roller is set with a radial jewel, and the edge is snailed, it is held by two screws on an integral collet on the staff.

Balance: Bimetallic four-armed balance with cylindrical brass compensation weights. The steel parts of the balance are blued, and it is fixed with two screws to a brass collet on the staff. Steel timing screws are set in the rim at the ends of the arms. Diam. 27·3 mm, h. 2·1 mm.

Balance spring: Blued steel conical spring of 13½ turns without terminal curves. The smaller end clamped concentrically to the stud, the larger end similarly clamped to the stud. This has three levelling screws.

Going-train counts:
Great wheel (fusee) 104 teeth, 8 turns of groove
Centre pinion 26 leaves, wheel 128 teeth, 4 arms
Third pinion 16 leaves, wheel 120 teeth, 4 arms
Fourth pinion 16 leaves, wheel 140 teeth, 4 arms
Escape pinion 14 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000.

Motion work:
Cannon pinion 18 leaves, minute pinion 16 leaves
Hour wheel 64 teeth, minute wheel 54 teeth

The minute wheel and pinion are pivoted between a cock and the front plate. The hour wheel runs on a steel pipe set in a bridge over the cannon pinion.

Winding work: A brass wheel of 50 bevel teeth is carried on a steel shaft pivoted in brackets on the inside of the movement canister. It has a squared end for winding. The wheel is in permanent mesh with a steel bevel wheel of 50 teeth on the squared fusee arbor.

Provenance: Ilbert collection; Ilbert in his inventory notebook records the acquisition of this chronometer from Messrs Breguet in Paris in July 1939. A certificate from Messrs Breguet accompanies the chronometer to guarantee that it was made more than 100 years before the date of its importation into Great Britain (reg. no. CAI-1953). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Bibliography: Bertele 1981, p. 193. J. C. Sabrier, *Henri Motel et la Chronométrie française dans la premiere moitié du XIXe siècle*, Ancaha Eté, 1979, No. 25, pp. 23–52.

17 AMAURY NO. 11995

1829–1830

CHRONOMETER *Plate 15a–f*

Signature: Engraved on the cuvette 'Amaury AU HAVRE DE GRACE no 11995' with an arrow through the top of the N; and the inscription: 'Echapement a la Arnold garni en pierres, 10 joy'x, balancier compense' (Arnold-type escapement, ten jewels, compensated balance).[1]

Case: Open face silver case with the No. 3919 and 5730, also 84 and the maker's mark MF. The French quality control mark for 1822–38. The middle of the case finely engine-turned. Slide to operate independent seconds mechanism at 6 o'clock. Front and back hinged. The movement fitted into a gilded brass drum to which the cuvette is hinged. This drum fitting into the case from the back and held by three radial screws on the edge of the dial. Diam. 58 mm, th. 18·4 mm.

Dial and hands: Curved enamel dial, slightly cracked. Arabic numerals. Secret signature 'Amaury au Havre' across the lower half of the dial in fine cursive script.[2]

Blued steel moon minute and hour hands and independent sweep centre seconds hand set between them

Movement

No ébauche marks, but the number 11995 stamped on the front plate under the dial.

Front plate diam. 49·3 mm; front plate th. 2·05 mm; frame h. 9·0 mm.

Frame: A nicely gilded brass frame made up of a massive front plate and a number of separate cocks screwed to it with blued steel screws. The going-train wheel carried on the back and the independent seconds train under the dial with the motion work. Two hanging barrels with a type of Geneva stop-work, one for each train, key winding.

Going train: Brass wheels not gilded but carefully made and crossed out, the top and bottom surfaces finished by flat burnishing or polishing. Steel pinions well polished. The fourth wheel pivot on the dial side extended so that it could have carried a subsidiary seconds hand.

Independent seconds train: Consisting of a great wheel integral with the smaller going barrel and four wheels and five pinions. The third of these wheels, on its large diameter pinion, running free on the cannon pinion and carrying the long independent seconds hand, the gear ratio between this wheel and the last pinion of the train is 60:1. The last pinion carries a small arm or flirt arranged to intersect a five-leaf pinion on the arbor of the escape pinion. A slide in the band of the case operates a level which releases the flirt. When the flirt is released it intersects the five-leaf pinion and is so positioned that it is released as each leaf of the pinion passes, that is nearly a turn at every sixth swing of the balance, or one second. As the flirt turns slowly forward against the pinion leaf the long seconds hand advances accordingly in jumps of almost a second, the completion of the whole of the seconds motion takes place at the instant of the next release. The seconds hand can be prevented from advancing if the slide is moved so that the flirt is held up. There is no means of setting the independent seconds hand to zero except by stopping it at that point. This system was superseded later in the nineteenth century by the invention of the chronograph mechanism.

Jewelling: The pivots of the fourth wheel of the going train and the escapement run in large well-made jewels either clear, or of a pale purple colour. Endstones are fitted for the balance. All the other pivots run in brass holes.

Escapement: A polished steel escape wheel with finely pointed inclined teeth and two pivoted detents. The escape wheel locked by the detent nearest to it which carries a jewel for the purpose and has a pivoted ruby roller on an arm. Unlocking is achieved by the other detent which has two arms, one in the path of the unlocking pallet on the balance staff, the other arm to contact the pivoted ruby roller on the first detent. Both detents are returned, the first against a stop, the second against the first, by spiral springs.

Impulse is given directly to a pallet on the balance staff by the escape wheel teeth.

Balance and balance spring: Blued steel spiral balance spring of 6 turns pinned to a steel stud on the front plate. A grained steel index with a tail moving over an engraved sector on the balance cock and 2 brass pins embracing the first turn of the balance spring. The index is held under a grained steel endstone plate.

Brass and steel bimetallic balance having a single crossbar. The segment compensation weights on the bimetallic rims with micrometric adjustment by a squared worm. This worm is in the body of the weights acting in a half thread form cut in the outside of each rim. Registration dots on the rims at each ninth turn. Diam. 17·5 mm, h. 1·29 mm.

Going-train counts:
Great wheel (barrel) 96 teeth 3 turn stop-work
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 72 teeth, 5 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 21,600

Independent seconds train:
Barrel 75 teeth, 4 turn stop-work
First pinion 10 leaves, wheel 64 teeth, 5 arms
Second pinion 8 leaves, wheel 75 teeth, 5 arms
Centre pinion 10 leaves, wheel 60 teeth, 5 arms
Fourth pinion 6 leaves, wheel 36 teeth, 4 arms
Flirt pinion 6 leaves

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

The hour wheel crossed out with four arms. The motion work gearing has a coarser pitch than the wheels of the independent seconds train.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1837).

Notes

1. Tardy 1971 gives Amaury as end of 18th century.
2. Secret signatures are only normally associated with A. L. Breguet.

18 DUCHEMIN

c. 1840

CHRONOMETER *Plate 16a–b*

Signature: On the cuvette 'E. No. 184 Duchemin A. PARIS'. On the dial 'Duchemin'.[1]

Dial and hands: Flat white enamel dial with flush subsidiary seconds, the feet pass through the front plate and are held with pins.

Blued steel moon hands.

Case: Open face silver case with a glazed back over the cuvette. Three small French hallmarks, a crayfish or lobster (in use 1822–38), a crab on the pendant and crab on the inside of the cuvette. Also the Paris guarantee mark for small work used after 10 May, 1838.

Movement

Front plate diam. 52·6 mm; movement h. over the barrel 10·9 mm

Frame: Lepine type of construction built up on a single thick plate and recessed under the dial. The brass parts finely frosted and gilded.

Barrel: Hanging going barrel with Breguet type of geared stop-work on the cover allowing four turns of wind.

Going train: A small train in relation to the space available. The brass wheels left polished, the pinions well finished and polished. The third pinion partly turned away to clear the fourth wheel.

Jewelling: The pivots of the balance staff in pierced jewels, with a ruby endstone on the balance cock and a steel end plate for the lower balance staff pivot.

Escapement: A form of pivoted detent escapement with all the safety action on the detent. The escape wheel teeth are normally locked by a steel piece screwed to the tail of the detent. Near the nose of the detent a steel pin intersects the teeth when the escape wheel is unlocked. If the detent unlocks at the wrong moment for any reason this pin causes it to relock before the wheel can advance by more than a tooth space. The normal impulse roller is replaced by an obtuse angled pallet with an impulse plane that leans towards a radial to the tip an an angle of about 40°, the front part of the wheel teeth showing signs of wear. The discharge roller is made from a piece of steel with a protrusion to intersect and unlock the detent. The passing spring has a tiny foot screwed to the underside of the tail of the detent and banking at the nose is against a brass pin.

Balance and spring: Plain gilded brass three-armed balance with various steel screws set in the outer edge; the screws probably not there originally since the case has been relieved at the hinge in a most unworkmanlike manner to clear them. Diam. 21·2 mm, h. 1·2 mm.

Flat spiral steel balance spring of $9\frac{1}{2}$ turns, with a separate overhanging piece for the stud and an index on the balance cock. No thermal compensation. The pins for the index are set in a separate steel piece held by a single screw and a steady pin to the overhanging part of the index. There are holes for pins at a closer radius to the balance staff, and other signs of alteration, so possibly a compensation curb was once fitted.

Going-train counts:

Great wheel (barrel) 96 teeth
Centre pinion 12 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 60 teeth, 5 arms
Escape pinion 10 leaves, wheel 10 teeth, 4 arms
Beats per hour: 7,200

Motion work:

Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

The minute and hour wheels gilded.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1941 (reg. no. CAI-1730).

Note

1. Duchemin was working at the Quai de l'Horloge in 1820 and in the Place du Chatelet, 1820-40.

19 MAKER UNKNOWN (*Swiss or French*)

c. 1840

CHRONOMETER MOVEMENT *Plate 16c–f*

Dial and hands: Enamel dial with curved edge.

Hands missing.

Movement

Ebauche marks 89 and underneath 653.

Front plate diam. 44·7 mm, frame h. 4·2 mm

Frame: Lepine-type calibre with hanging barrel, and with separate cocks on both sides of the front plate to make the movement as thin as possible. Brass parts gilded (see Note).

Going barrel: The usual construction, keywind with four-turn Geneva stop-work on the cover end.

Going train: The usual construction. The wheels not gilded.

Escapement: Pivoted detented escapement specially adapted for a thin calibre. The detent is returned by a leaf spring and the locking stone protrudes sideways from the body of the detent. Steel impulse roller with radial impulse plane, jewelled discharge roller.

Balance: Plain brass three-armed balance, the flat spring with an index on the balance cock. No compensation. Diam. 18·1 mm, h. 0·48 mm.

Balance spring: Blued steel spiral spring of 10 turns, no terminal curves.

Going-train counts:

Great wheel (barrel) 80 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 60 teeth, 4 arms

Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 8 leaves
Hour wheel 32 teeth, minute wheel 30 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1611).

Note: Although not made for the greatest accuracy, this movement is an example of the use of a precision escapement in a very thin movement, presumably in the hope of a better performance than would be obtained with a cylinder or duplex escapement. The calibre was probably one originally fitted with a cylinder escapement. It retains the adjustable chariot to move the balance assembly towards or away from the escape wheel, and the parts used to convert it are of a different standard and finish from the movement. The main plate has a split (no doubt caused whilst being worked upon) from the slot clearing the pallets to the outside edge.

20 HENRI ROBERT

c. 1849

MARINE CHRONOMETER *Plate 17a–d*

Signature: On the dial only 'H$^{\text{RI}}$ Robert Paris 58' (the number within the seconds circle).[1]

Box: The movement contained in a brass bowl with a friction-tight glazed bezel. There was once an escutcheon plate with an eccentric winding hole on the bottom of the bowl. The movement is fitted into a very thick flanged ring the edges of which are turned to fit into the bowl and which is screwed to the bowl. This ring also takes the bezel. The bowl is gimballed in a mahogany box, the gimbal ring having adjustments to level the chronometer and with a lock in the near right-hand corner of the box. The box has a glazed panel in the top, with a hinged lid and catch, it also has a lock but no carrying handles. The winding key fits in a hole in a gusset in the near left-hand corner, and around the edge of the top of the lower half of the box is glued a strip of green baize to exclude dust. Base 169 mm square; sides 161 mm square; h. 178 mm.

Dial and hands: Flat silvered engraved brass dial with a granular surface finish, the engraving filled with black wax. The chapter ring is not central with respect to the bezel.

Hands of blued steel.

Movement:
Movement ring flange diam. 91·0 mm (reduced to 84·0 mm); overall ht. 23·2 mm; dial and dial plate diam. 78·2 mm; front plate diam. 78·2 mm; frame th. over barrel cock 34·4 mm.

Frame: A most unusual construction in which the lower pivots of the going train run in the dial plate. The latter has three turned pillars passing into the front plate, held by pins. The dial is secured to the dial plate by two screws from the back and is hollowed out for the motion work; this is carried on a separate plate screwed to the inside. The barrel cock, balance cock and the other smaller cocks on the front plate are made of a red brass. Removal of the balance cock screw causes a steel rod carried on a springy steel arm to rise into the path of the escape wheel teeth thus locking the train. The balance is also protected by a stout pin set in the bezel ring. The movement is fitted into a thick turned ring of brass with the dial resting against a shoulder and secured by three eccentric brass plates each held with a shoulder screw on the front plate and passing into slots in the ring. There is also a positioning peg in the edge of the front plate and a corresponding slot in the ring. The visible brass parts are spotted.

Going barrel: Fitted with an eight-turn Geneva stop-work on the cover end. The cover is prevented from rotating by a steel piece held with a screw so that it overlaps the edge and passes into a slot in the barrel wall. The barrel arbor has a snailed brass boss with a steel hook passing into it. The mainspring is hooked at its outer end to a small steel piece screwed and steady pinned to the barrel wall. There is also a bride. The spring is signed 'Bourquin Mars 1849' and is of exceptionally fine quality, beautifully blued and finished and with a slight taper, getting thinner towards the inner end.

Going train: Well made, the pinions and arbors well finished and polished, the brass wheels circular grained.

Jewelling: The pivots of the fourth and escape pinion arbors and balance staff in pierced jewels. Diamond endstones are used for the balance cock and the rear fourth bearings, and ruby for the rear escape pinion and the lower balance staff bearings. The detent pivots are run in holes in the brass, with a steel endpiece on the rear cock.

Escapement: Pivoted detent escapement, the brass escape wheel with arms and rim sunk out on the underside and held with two screws on a brass collet. The detent with a spiral return spring, cylindrical locking stone with a ground locking surface, and banked by its tail against a brass peg set eccentrically in a screw head. The steel impulse roller with its edge and notch polished, secured by a single screw to a flange on the extended collet on which the balance is fixed. The impulse jewel is set leaning towards a radial to the tip. The steel discharge roller has two adjusting flats and a flat-sided jewel.

Balance: Bimetallic two-armed balance with screws and segment weights, and quarter screws in brass pieces screwed to the inside of the rim and set above the level of the other screws. It is secured to a brass collet on the staff by two screws. Diam. 27·2 mm, h. 2·6 mm.

Balance spring: Blued steel helical spring of 11¼ turns, with terminal curves, pinned to a rectangular steel collet, and clamped to a steel stud which is itself clamped under a steel plate on the end of the balance cock by two screws.

Going-train counts:
Great wheel (barrel) 112 teeth, 8 turn stop-work
Centre pinion 16 leaves, wheel 96 teeth, 5 arms
Third pinion 12 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 90 teeth, 5 arms
Escape pinion 12 leaves, wheel 15 teeth, 4 arms
Beats per hour: 13,500

Motion work:

Cannon 'pinion' 25 leaves, being a brass wheel on a steel cannon, minute pinion 10 leaves

Hour wheel 60 teeth, minute wheel 50 teeth

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of this chronometer in 1932 from Collett (reg. no. CAI-1955). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Note

1. Henri Robert's dates, as recorded by Tardy 1971, are 1794–1874; an eminent maker, he published a number of papers on different aspects of Horology.

Bibliography: M. J. Berlioz, *Rapport sur d'horlogerie a l'exposition de 1878*, Paris, 1878, 14 figs in pl. 1.

21 JOHN FORREST

c. 1870

CHRONOMETER MOVEMENT *Plates 17e–f, 18a–c*

Signature: On the back plate 'John Forrest London no 5478 Chronometer maker to the Admiralty'. On the dial 'CHRONOMETER 5478'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds dial and sunk centre to the up-and-down dial. The dial attached to the front plate by three feet and pins, one foot machined so as to clear the keyless work spring.

Blued steel hands, the up-and-down hand missing.

Movement:

Ebauche marks 16, 0, 82 (or S2) and underneath 5478.

Front plate diam. 44·5 mm; back plate diam. 42·6 mm; frame th. 9·1 mm.

Frame: Massive half plate construction with three turned pillars, the unusually thick back plate (2·1 mm) secured by recessed blued steel screws. The movement was secured in its case by a peg in the edge of the front plate and two dog screws on the edge of the back plate. All the brass parts gilded.

Mainspring barrel and barrel arbor assembly: A very unusual arrangement: the mainspring is contained in a barrel forming part of a bridge and secured open side down on the front plate. The barrel arbor is pivoted in the front plate and in the barrel. Stop-work, now missing, was fitted on the top of the barrel.

The barrel arbor has an integral winding ratchet wheel at about the middle. The boss to which the spring is hooked is held with a transverse pin to the arbor. Between this boss and the winding ratchet wheel is sandwiched a thin steel wheel with ratchet-shaped teeth on its edge and carrying the clicks and springs to work with the winding ratchet wheel. This wheel is similar in appearance to a fusee maintaining power ratchet wheel and performs the same function; it is free to turn on the arbor. The great wheel fitted with the maintaining power spring is held on the arbor by a collar pinned through the arbor. The whole barrel arbor assembly can be considered as a fusee fitted with maintaining power in which the fusee itself has been replaced by a boss hooked directly to the mainspring. A maintaining detent and spring are provided to work with the maintaining ratchet wheel. This complicated arrangement is to protect the going train in the event of mainspring breakage.

Keyless work: The end of the barrel arbor passing through the front plate is squared and carries a steel winding wheel held on with a pin. This wheel is in permanent mesh with another smaller steel wheel pivoted on a shoulder screw. Both these wheels turn during winding and going. A type of rocking bar keyless work is fitted in which the two smaller rocking bar wheels are held out of mesh with all the other wheels except the central larger wheel. Two springs hold the rocking bar in its middle position. Two push-pieces must have been provided in the original case, one on each side of the pendant, each acting on one end of the rocking bar. When looking at the movement from the front with the dial removed the left-hand push-piece would have caused the rocking bar to tilt clockwise and mesh the wheels for hand setting. There are two intermediate hand-set wheels to convey motion to the minute wheel.

Up-and-down indicator: On the end of the barrel arbor is fitted a small pinion meshing with a brass wheel pivoting on a pillar nearby. An indicator hand was fitted on a cannon integral with the brass wheel. Since the barrel arbor turns in one direction during winding and the other during running this simple system can be used.

Going train: Constructed in the usual way and laid out in a similar way to that for a reversed fusee. The centre arbor hollow for the square-ended arbor carrying the cannon pinion. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escape pinion and balance staff with endstones.

Escapement: Pivoted detent escapement, the brass escape wheel not sunk out for lightness, but finished with the upper and lower surfaces burnished. The polished steel impulse roller with the impulse surface slightly rounded and inclined so that the outer end leans towards a radial to the tip. The jewelled steel discharge roller with an adjusting flat, fitted between the impulse roller and the brass collet on which the balance is mounted. The detent pivoted near the edge of the frame and having both the gold passing spring and the leaf return spring pinned into holes in a central boss. The locking stone made from a half-round piece of ruby. Banking provided by a screw set in a polished steel arm overhanging the escape wheel. The end of the screw banks against the locking stone pipe. Locking of the escape wheel is carried out on the tooth after that which has just given impulse, the detent being returned after unlocking by the leaf spring bearing against a brass peg set in a sink in the front place. The pivoting point of the detent is set inside a tangent to the locked tooth so that the detent and horn are straight.

Balance: Bimetallic two-armed balance with a mixture of large gold screws and small steel screws between them. Diam. of rim 14·4 mm, h. 1·68 mm.

Balance spring: Blued steel helical spring of $8\frac{1}{2}$ turns, with terminal curves, free sprung to a polished steel diamond-shaped stud on the balance cock and a brass counterpoised collet.

Going-train counts:
Great wheel 90 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 6 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 30 teeth

Keyless work:
Central rocking bar wheel 56 teeth
Winding rocking bar wheel 28 teeth
Hand set rocking bar wheel 24 teeth
Intermediate winding wheel 18 teeth
Barrel arbor bar wheel 38 teeth
Intermediate hand-set wheels, each 18 teeth

Up-and-down indicator:
Driving pinion 10 leaves
Wheel carrying the hand 60 teeth

Provenance: Ilbert Collection; purchased by Ilbert from J. W. Benson in 1935 (reg. no. CAI.1597).

22 JULES JÜRGENSEN
c. 1870

CHRONOMETER *Plates 18d–e, 19a–c*

Signature: On the bridges 'Jules Jürgensen Copenhagen No 12422'. On the dial 'Jules Jürgensen Copenhagen'.[1]

Case: Later metal case, the front bezel and back hinged to the middle opposite the pendant. All three decorated with an engraved or embossed design, and with engine-turned decoration on the back. The cuvette glazed. The movement fitted into a metal ring fitting tight in the case. Diam. 55·6 mm, h. over glass 18·4 mm

The inside of the back marked 'C.W.C. Co. Trade Mark' and '596766'. The middle marked '6766' and 'Pat'd Dec 7 86'.

The pendant bow extending inside the hollow pendant and arranged to operate a sleeve for the hand set when turned to rest against the front or back of the case.

Dial and hands: Finely marked flat enamel dial with sunk subsidiary seconds, held friction tight in a white metal ring snapping onto the edge of the front plate, and with one positioning peg.

Blued steel hands, the seconds hand not original.

Movement
Ebauche marks: stamped on the front plate under the dial 'Jules Jürgensen of Copenhagen 12422', also the scratched number 66724 over the letters of the inscription.

Front plate diam. 45·2 mm; bridge overall diam. 43·9 mm; frame th. 7·0 mm; front plate h. 3·4 mm.

Frame: Open bridge construction built up on a massive front plate with turned or milled recesses for the motion and keyless work and for the going train and escapement parts. The frame made of an alloy of nickel brass, the surfaces finished in the most careful and refined way with spotting under the dial and fine snailing on the visible surfaces at the back.

Going barrel: Of the hanging barrel type and fitted with Geneva stop-work, the Maltese cross missing.

Going train: The high numbers of the pinions give an indication of the quality of the train. The crossings of the gilded brass wheels very carefully filed with a rounded bevel on the upper surfaces, the steel parts well finished and polished.

Jewelling: The centre arbor rear pivot, and those of the third and fourth arbors in pierced jewels with curved faces against the pivot shoulders. All the pivots of the escapement arbors in pierced jewels with endstones. The detent and escape wheel upper endstones set in red gold plates.

Escapement: Pivoted detent, the gold escape wheel very finely crossed out and finished. The pivoted detent with spiral return spring, half-round locking stone and gold passing spring held away from the body of the detent by the short horn with its end formed at right angles to the rest. The centre line of the detent planted outside a tangent to the locked tooth, and locking on the second tooth after the one which has just given impulse. The detent banked by the extending locking stone passing into an eccentric hole in a steel plate set in the front plate. Jewelled impulse roller, the jewel set with its impulse face leaning slightly towards a radial from the centre to the tip. The discharge roller a later replacement made of steel.

Balance: Bimetallic two-armed balance with gold screws, the steel parts blued. The arms join the rim midway between the top and bottom of the rim. Diam. 20 mm, h. 1·6 mm.

Balance spring: Blued steel spiral spring of $12\frac{1}{2}$ open coils and with an overcoil and terminal curve having a reversed curve. A steel finger piece is attached to the end of the last turn of spring, before the overcoil, by a brass pin clamping the spring in a hole. This works in conjunction with an amplitude limiting device. Round brass collet; polished steel stud held by 2 screws on the balance cock. Polished steel index with a long tail passing over a vernier scale on the centre and third bridge.

Amplitude limiting device: A pin (now missing) standing up on one balance arm passes between two prongs set in a block and pointing down from the underside of the balance cock. The finger piece carried on the balance spring and described earlier is carried outwards by the expansion of the balance spring and is so arranged that at a certain amplitude it closes the gap between the two prongs before the pin on the balance arrives to pass through. Being unable to pass, the balance is thus prevented from attaining a larger amplitude.

Keyless work: Swiss sliding-pinion keyless work with massive steel winding wheels. The hand set operated by moving the pendant bow as described under Case details. In either position a pair of levers is set in motion by a sleeve in the pendant tube to move the sliding pinion into engagement with the first of two intermediate hand-set wheels transmitting motion to the minute wheel.

Going-train counts:
Great wheel (going barrel) 96 teeth

Centre pinion 12 leaves, wheel 96 teeth, 5 arms
Third pinion 12 leaves, wheel 90 teeth, 5 arms
Four pinion 12 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 16 leaves, minute pinion 9 leaves
Hour wheel 48 teeth, minute wheel 36 teeth

Keyless work:
First winding pinion or crown wheel 18 winding teeth, 12 ratchet teeth
Intermediate winding wheel 38 spur teeth and 38 bevel teeth
Barrel ratchet wheel 40 teeth
Sliding pinion 12 ratchet teeth and 22 bevel teeth for hand setting
First intermediate hand-set wheel 25 teeth
Second intermediate hand-set wheel 29 teeth

Provenance: Ilbert collection. Purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1728).

Note

1. Although signed *Jules Jürgensen, Copenhagen*, the watch would have been made at Le Locle in Switzerland where Jules Jürgensen spent most of his life. As far as the author knows, all the very high-class watches made by Jules Jürgensen were signed in this way; see Chamberlain 1941, pp. 413–15. A similar watch compete in its original silver case, the movement numbered 14424, is in the Museum of La Chaux-de-Fonds, Switzerland.

23 P. NORRIS

Second half of the 19th century

CHRONOMETER MOVEMENT *Plates 19d–e, 20a*

Signature: On the back plate 'P. Norris Liverpool no 5421'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, attached to the front plate by three feet and pins. On the back of the dial, in the enamel, the number 12 in green.

Blued steel hands.

Movement

Ebauche marks 16*1 5421 C.S.

Front plate diam. 44·8 mm; back plate diam. 41·9 mm; frame th. 7·9 mm.

Frame: Half plate construction with three turned pillars, the back plate retained by recessed blued steel screws. The movement held in its case by a hinge at XII o'clock and a peg in the edge of the front plate opposite. All the brass parts gilded.

Fusee: Keywind fusee, with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work under the dial in a shallow recess on the front plate. The barrel arbor with an extended square on that end only.

Going train: The centre arbor hollow for the squared hand-set arbor carrying the cannon pinion. The brass wheels with a burnished finish on both sides and not gilded. The steel pinions well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escape wheel and balance staff with endstones.

Escapement: An unusual pivoted detent escapement, the rather heavy brass escape wheel not sunk out for lightness. The detent integral with a square boss on its arbor. The boss drilled and fitted with two leaf springs, one to provide passing action and made of a material resembling gold, the other of steel and acting as the return spring, its end bearing on a pin set in the fourth arbor cock. Banking for the detent provided by a brass piece partly concentric with the balance staff contacting the locking stone boss, there is no adjustment for the depth of locking. The locking stone itself a half-round jewel.

The usual jewelled, polished steel discharge roller, without an adjusting flat, fitted between the impulse roller and the balance. The steel impulse roller not jewelled and with a polished impulse face leaning towards a radial to the tip. The edge and bottom and the roller also polished as well as both sides of the impulse notch, which ends in a hole in the roller to enable the balance to be removed without disturbing the detent.

Balance: Bimetallic two-armed balance with gold screws and quarter screws. Diam. 16·8 mm, h. 1·79 mm.

Balance spring: Blued steel helical spring of $6\frac{3}{4}$ turns, with terminal curves, free sprung to a polished steel stud on the balance cock and a brass, poised collet.

Going-train counts:
Great wheel (fusee) 78 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1739).

Note: The ébauche appears to have been originally intended for a spring detent escapement, filled holes around a sink concentric with the balance staff indicate where the spring detent banking would have been. The alterations and additions for the pivoted detent have been worked in with the minimum of modification to the original plan.

Baillie 1951, refers to this movement and lists a Patrick Norris, Liverpool, 1781-1829. However a more likely period is the second half of the nineteenth century.

24 MAKER UNKNOWN, but Swiss

c. 1870

CHRONOMETER *Plate 20b–c*

Case: Open face silver case without fly or lock springs. Numbered inside the back 163 and 13266. The cuvette engraved 'Chronometre' in a floral cartouche, with an engine-turned edge decoration. The back and middle of the case also decorated with engine turning. Bow has an English hallmark and does not belong to the rest of the case. Diam. 50·4 mm, h. over the glass 14·4 mm.

Dial and hands: Flat enamel dial with sunk subsidiary seconds. Hands are replacements, seconds hand missing.

Movement
Ebauche marks 2234
Front plate diam. 45·3 mm; frame h. 6·8 mm.

Frame: Lepine-type calibre built up on a thick front plate. The front plate with an eccentric turned sink under the dial, for a semicircular bridge with the lower train and escapement bearings. The visible parts frosted, and all brass parts electro-gilded to a pale colour.

Going barrel: Hanging barrel, keywound, once with Geneva stop-work on the cover end.

Going train: Conventional layout and construction, the brass wheels frosted and gilded to match the frame.

Jewelling: The third, fourth and escapement pivots in pierced jewels, the balance staff and detent rear pivots with endstones.

Escapement: Pivoted detent escapement of typical construction. The steel impulse roller with impulse plane leaning slightly towards a radial to the tip. Steel discharge roller possibly a later replacement.

Balance: Bimetallic two-armed balance with curved arms and brass compensation screws. Diam. 17·5 mm, h. 1·2 mm.

Balance spring: Blued steel spiral spring of about 11½ open coils with a reverse curve overcoil. The balance cock carries a polished steel index and a plate with 2 screws to clamp the stud.

Going-train counts:
Great wheel (barrel) 80 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 60 teeth, 5 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 8 leaves
Hour wheel 32 teeth, minute wheel 30 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Ash in 1932 (reg. no. CAI.1836).

25 MAKER UNKNOWN, but Swiss
Late 19th century

CHRONOMETER MOVEMENT *Plates 20d–e, 21a–b*

Dial and hands: Flat enamel dial with sunk subsidiary seconds, secured to the front plate by two feet and eccentric dog screws. Plain Roman hour numerals, Arabic seconds numerals. The back of the dial marked B.F. and an illegible word beginning T or SL, also the number 2144 scratched in the enamel.

The hands missing.

Movement
Ebauche marks 2144
Front plate diam. 45·1 mm; back plate diam. 42·6 mm; frame h. 7·4 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate retained by recessed blued steel screws. A separate sub plate on the dial side of the front plate carries the lower bearings of the third, fourth and escapement arbors. The movement was held in its case by a peg and two dog screws in the edge of the front plate. The brass parts electro-gilded a whitish yellow.

Fusee: Keywind fusee fitted with Harrison's maintaining power with a steel ratchet wheel and four-turn Geneva stop-work in a recess on the dial side of the front plate. Setting-up-work also on the dial side of the front plate, the barrel arbor with an extended square on that end only. The barrel with a flange on the cover end. A chain guard is fitted between the barrel and the balance. The great wheel and maintaining ratchet wheel are held on the bottom of the fusee by a steel plate in a recess in the great wheel and three screws passing into a boss left standing on the ratchet wheel and on which the great wheel also pivots. The squares for both winding and hand setting protected by dust-excluding tubes held on with three screws each.

Going train: Conventional layout and construction, the centre arbor hollow for the squared hand-set arbor carrying the cannon pinion. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. The train jewels with curved faces (*bombé*) against the pivot shoulders.

Escapement: Pivoted detent escapement, the gold escape wheel lightly made and crossed out, the arms sunk below the level of the rim and teeth. The polished steel impulse roller set with a radial jewel, the discharge roller also polished, with one adjusting flat, and jewelled with a straight-sided jewel in a similar slot. The pivoted detent lightly made with the top surfaces bevelled and polished, the half-round locking stone protruding on the lower side of the detent and banking against a screw head set in the subplate. Locking occurs on the second tooth after that which has just given impulse and the detent is planted with its pivoting point well outside a tangent to the locked tooth. The passing spring appears to be made of gold and is secured to the detent arbor boss by a screw. The blued steel return spring is attached to a brass collet above the arbor boss, and to a polished steel arm screwed in a shallow recess in the front plate.

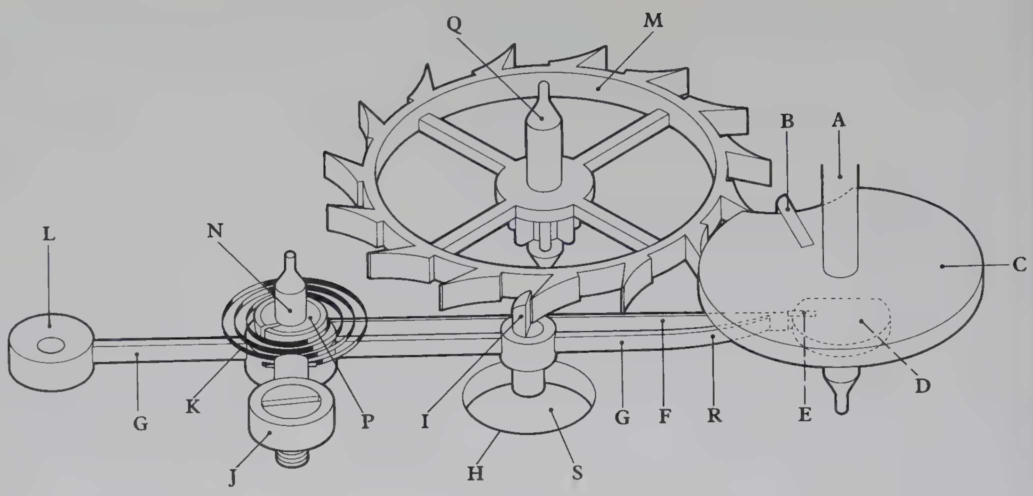
Balance: Bimetallic two-armed balance, the arms of sage-leaf pattern, with gold quarter screws, the remainder brass. Diam. of rim 14·7 mm, h. 1·78 mm.

Balance spring: Blued steel helical spring of 9 turns, with terminal curves, pinned to a rectangular brass collet slit to spring

FIGURE 2

Swiss pivoted detent escapement

A	balance staff
B	impulse jewel
C	impulse roller
D	discharge roller
E	discharge jewel
F	passing spring
G	detent
H	locking jewel pipe
I	locking jewel
J	stud for detent return spring
K	detent return spring
L	counterpoise
M	escape wheel
N	detent staff
P	return spring collet
Q	escape pinion
R	detent horn
S	hole for banking detent



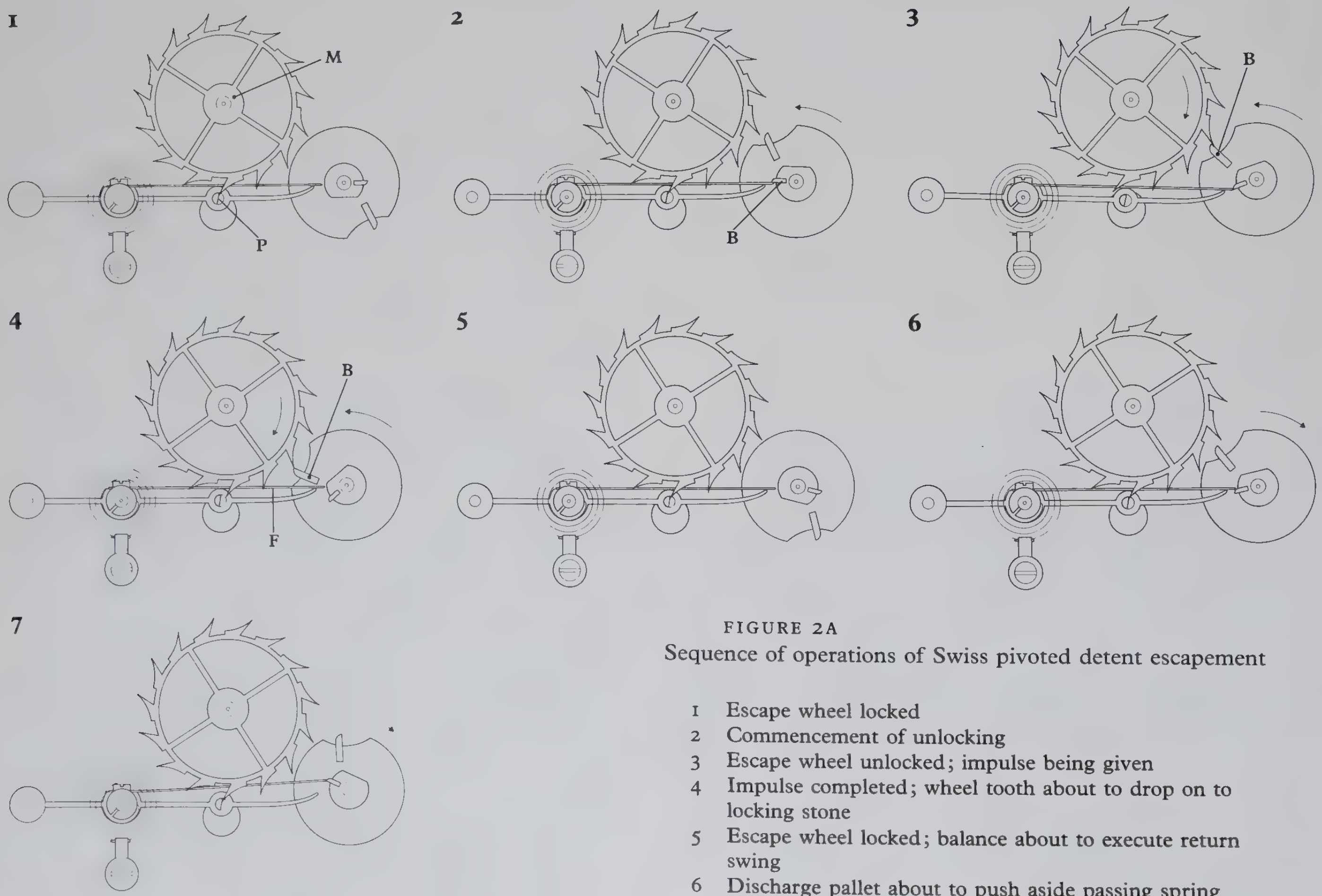


FIGURE 2A

Sequence of operations of Swiss pivoted detent escapement

1 Escape wheel locked
2 Commencement of unlocking
3 Escape wheel unlocked; impulse being given
4 Impulse completed; wheel tooth about to drop on to locking stone
5 Escape wheel locked; balance about to execute return swing
6 Discharge pallet about to push aside passing spring
7 Discharge pallet about to leave passing spring

it onto the balance staff, and a small brass stud held under a steel plate on the balance cock.

Going-train counts:
Great wheel (fusee) 76 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; Ilbert purchased the piece from Malcolm Gardner in 1932 (reg. no. CAI-1826).

26 MAKER UNKNOWN, but Swiss
Late 19th century

CHRONOMETER MOVEMENT *Plate 21a–c*

Dial and hands: None.

Movement:
Ebauche marks 12,169.
Front plate diam. 42·9 mm; frame h. 5·5 mm; front plate th. 3·0 to 3·05 mm (sunk out to 1·55 to 1·60 mm).

Frame: Bar movement built up on the front plate, recessed under the dial and with a semicircular bridge for the third, fourth and escapement lower bearings. No provision for a dial or for holding the movement in a case.

Going barrel: Hanging barrel with four-turn Geneva stop-work. The barrel arbor drilled for a retaining pin for the stop-work finger. The cover positioned by a pin half in the barrel wall which fits into a matching slot in the cover.

Going train: The pinions, arbors and pivots polished, the brass wheels left rough and awaiting finishing and gilding. The centre pinion drilled for the hand-set arbor.

Jewelling: Only the pivots of the escapement in jewelled holes, with endstones set in plates.

Escapement: Pivoted detent, the brass escape wheel with the crossings sunk below the level of the rim and teeth. The pivoted detent with poising tail and top surfaces bevelled and polished. Jewel locking stone serving also for banking in a hole in the front plate. Spiral return spring of $7\frac{1}{2}$ tight coils pinned to a brass collet and polished steel stud. Gold passing spring screwed to the detent boss. The impulse roller with polished edge and crescent, and with a radial impulse pallet. The discharge roller made from a solid piece of ruby and held with a brass cap on the end of the balance staff. The detent planted outside a tangent to the locked wheel tooth, this tooth being the second after that which has just given impulse.

Balance: Bimetallic two-armed balance, the arms meeting the rim about half way up. The compensation screws probably a low carat gold alloy. Diam. 17·2 mm, h. 1·39 mm.

Balance spring: Blued steel open coiled spiral spring of $11\frac{1}{8}$ turns, with an overcoil and terminal curve with reversed curve. An index fitted on the balance cock.

Going-train counts:
Great wheel (barrel) 76 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work: Missing.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1931 (reg. no. CAI-2388).

27 MAKER UNKNOWN, but Swiss
late 19th century

CHRONOMETER MOVEMENT *Plate 22a–d*

Dials and hands: Flat enamel canister dial with sunk subsidiary seconds, with a single positioning peg. Up-and-down indicator concentric with the centre and registering over a graduated sector in the upper half of the dial, with thirty large divisions. The intermediate divisions, and the words ‘Haut’ and ‘Bas’ written in red enamel.

Only the up-and-down indicator hand of blued steel remaining.

Movement
Ebauche marks 26096.
Front plate diam. 45·7 mm; frame h. 9·0 mm.

Frame: Built up on the front plate, and made of nickel silver. The movement was positioned by two pegs in the edge of the front plate, and two dog screws.

Fusee: Reversed fusee fitted with Harrison’s maintaining power, the maintaining ratchet wheel of steel. Geneva stop-work fitted on the dial side of the front plate. Setting-up-work on the bridge over the barrel, the ratchet wheel with a spring ratchet, the barrel arbor with an extended square on that end only. The barrel with a flange on the opposite end to the cover.

Keyless work: The winding stem carries a crown and a castle wheel as in Swiss push-piece hand-set keyless work. The crown wheel is in permanent mesh with a steel wheel pivoted on a plate able to rock about a stout steel pillar in the front plate. On pressing a push-piece integral with the rocking plate, the latter turns and is then held by a spring operated catch, with the steel winding wheel in mesh with a larger steel wheel squared to the fusee arbor. Turning the winding button then winds the mainspring. A peg carried on the Maltese cross of the stop-work releases the catch holding the rocking plate when the mainspring is fully wound. Another push-piece would be provided in the band of the case to operate on the return spring of the castle wheel, causing this to slide and engage with the intermediate hand-set wheel for setting the hands.

Going train: Conventional train and layout, but with the addition of an extra pinion meshing with the third wheel, having an extended pivot carrying the seconds hand. A light friction spring bears on the arbor to take up the backlash in the gearing. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The centre upper pivot and those of the rest of the going train and escapement in pierced jewels, those of the escapement with endstones. The maintaining detent pivots most unusually also in pierced jewels. All the visible jewels at the back of the movement in gold settings and fixed in recesses with polished steel screws.

Escapement: Pivoted detent escapement, the gilded brass escape wheel very lightly crossed out with the arms sunk below the level of the rim and teeth. The detent returned by a spiral spring and locking on the second tooth after the one which has just given impulse. Banking by the lower end of the locking stone against the edge of a hole in the escapement subplate. The locking stone missing. A gold passing spring held by a single screw to the detent near the arbor boss. The polished steel impulse roller with a jewel set with its impulse surface radial to the centre. The polished steel discharge roller jewelled with a flat slip of ruby, and having two notches for adjusting the escapement.

Balance: Two-armed double-sunk bimetallic balance (see Charles Nephew, cat. no. 28 for a similar one). Gold compensation screws. Diam. of rim 15·0 mm, h. 1·55 mm.

Balance spring: Blued steel helical spring of 9½ turns, with a terminal curve at the lower end only, pinned to a stud clamped under a polished steel plate on the balance cock and to a wedge-shaped nickel collet. An index is fitted to the balance cock.

Amplitude limiting device: A pin set vertically in one balance arm passes at each swing through the slot in a block pointing vertically downwards from the underside of the balance cock. A piece of shaped brass wire attached to a small block pinned to the uppermost coil of the balance spring moves to close the gap in the block when the balance arc reaches just less than a turn in either direction.

Going-train counts:
Great wheel (fusee) 76 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

There is an extra fourth pinion of 10 leaves carrying the seconds hand on its extended lower pivot.

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel missing but would have had 40 teeth, minute wheel 36 teeth

Keyless work:
Crown wheel 17 spur, 10 ratchet teeth
Castle wheel 14 contrate and 10 ratchet teeth
Intermediate winding wheel 36 teeth
Winding wheel on the fusee arbor 45 teeth
First intermediate hand-set wheel 35 teeth
Second intermediate hand-set wheel 16 teeth

Up-and-down work: Pinion on the fusee arbor 15 leaves, meshing with a wheel of 120 teeth turning free on the hour wheel pipe and carrying the indicating hand. A long semicircular cut out in the up-and-down wheel through which the pipe on the minute pinion extends serves no apparent purpose.

Note: This movement resembles that of cat. no. 179.

Provenance: Ilbert Collection; purchased by Ilbert from J. W. Benson in 1935 (reg. no. CAI-3053).

28 CHARLES NEPHEW & CO, but probably Swiss
Late 19th century

CHRONOMETER MOVEMENT *Plates 22e–f, 23a–c*

Signature: On the back plate 'Charles Nephew & Co LONDON & CALCUTTA'; also on the dial and the number 57 over 1999.

Dial and hands: Flat enamel dial with Roman numerals with sunk subsidiary seconds, attached to the front plate by two feet and pins. The name and number painted in very small characters in the upper half of the dial.

The spade hands and the seconds hand of the characteristic Swiss purple/blue colour.

Movement
Ebauche marks B 877.

Front plate diam. 43·9 mm; back plate diam. 41·0 mm; frame h. 7·1 mm.

Frame: Continental three-quarter plate construction with three turned pillars, the back plate retained by recessed steel screws of a purple/blue colour. The movement hinge, case catch and spring attached to the front plate under the dial. All the brass parts gilded. The balance cock engraved with scrolling foliage.

Fusee: Keywind reversed fusee with Harrison maintaining power, steel maintaining ratchet wheel, polished steel maintaining detent, the return spring screwed and steady pinned to the inside of the front plate concentric with the great wheel. Geneva stop-work mounted on the bridge bearing for the fusee arbor pivot on the front plate under the dial. The barrel arbor with an extended square on the dial side of the front plate carries the polished steel setting-up-work.

Going train: The centre arbor hollow for the squared hand-set arbor which carries the cannon pinion. The steel pinions and arbors well made and polished, the brass wheels gilded.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. The train jewels *bombé*, and of a bright red colour on the back plate. The polished steel endstone plates on the front plate side of figure-of-eight shape. The balance cock endstone in a type of coquerette of polished steel. The last three features point to a Swiss origin as does the colour of the hands and screws.

Escapement: Pivoted detent escapement, the escape wheel locked on the second tooth after that which has just given impulse. The rim and teeth of the gilded brass escape wheel left standing proud of the deeply sunk arms. Polished steel impulse roller with radially set jewel, and discharge roller with two flats for adjusting, the jewel set in a straight-sided slot. The steel detent with half-round locking stone, held by a steel half-round wedge projecting from the underside and banking against an adjustable plug on the edge of a hole in the escapement bridge. The long return spring acting on a comma-shaped brass piece on the detent staff, and planted between the balance cock foot and the edge of the front plate. The steady pin for this spring is lodged in a slot in the edge of a brass plug set in the front plate, and provided with a screwdriver slot, like that for the detent banking, for adjustment of the spring tension. Later, crudely made, white metal passing spring attached by a screw to the detent boss.

Balance: Double-sunk two-armed bimetallic balance with gold timing nuts at the ends of the arms, and compensation screws. Diam. 16·2 mm, h. 1·26 mm.

Balance spring: Blued steel helical spring of 10 turns, with terminal curves, free sprung to a polished steel stud on the balance cock, and a counterpoised, slotted bass collet.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1610).

29 AMI SANDOZ AND SON, Switzerland
Late 19th century

CHRONOMETER MOVEMENT *Plate 23d–e*

Signature: On the dial 'Ami Sandoz & Son N°. 90964'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds. Marked on the reverse 90964. Two dial feet pass through the pillar plate and are retained by two screws.

The hour hand broken, the minute and seconds hands blued steel with gilding; unusual tail to the seconds hand.

Movement
Ebauche marks 90964.

Front plate diam. 45·1 mm; frame h. 7·8 mm; front plate th. 2·80 mm reduced to 1·55 mm.

Frame: A type of three-quarter-plate construction with three turned pillars. The back plate is pierced and engraved in the form of an Imperial Russian double-headed eagle holding an orb and sceptre in its claws and retained by recessed blued steel screws. The front plate with separate subplates under the dial for the lower bearings of the barrel arbor and those of the fourth and escapement arbors. The movement was retained in its case by a peg and two dog screws on the edge of the front plate. The frame made of nickel brass with gilded decoration in the engraving, the front plate with a sunray pattern on the inner surface.

Going barrel and keyless work: The going barrel of nickel brass, with four-turn Geneva stop-work on the cover end. Sliding pinion type of keyless work; hand setting operated by a push-piece in the band of the case. The transmission gearing for winding with 'Wolf tooth' form. The mainspring marked 'J. Robert', probably the original spring. The winding arbor in two parts, the part remaining in the frame with a squared hole for the now missing pendant.

Going train: Wheels of red gold, burnished flat on both sides. The pinions and arbors well finished and polished, the centre pinion hollow for the arbor carrying the cannon pinion.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A diamond endstone set in a polished steel ring on the balance cock. An extra non-functional decorative endstone in a screwed setting on one of the eagle's heads on the back plate, to balance the pierced jewel on the other.

Escapement: Pivoted detent escapement with the escape wheel locked on the second tooth after the one which has just given impulse. The red gold escape wheel lightly crossed out, and with the arms sunk below the level of the rim and teeth. The polished steel impulse roller with a jewel leaning slightly towards a radial to the tip. The steel discharge roller with a straight-sided slot for the jewel and two crescent-shaped grooves for adjusting, only the edge polished.

The pivoted detent with spiral return spring, gold passing spring, the end of the horn formed at right angles to the rest to hold the passing spring clear of the detent. Banking against the lower extension of the half-round locking stone against a flat on the edge of the head of a screw in a recess in the escapement bridge.

Balance: Two-arm compensation balance with brass screws. Diam. 18·0 mm, h. 1·60 mm.

Balance spring: Blued steel helical spring of 7 turns, with terminal curves, free sprung to a stud clamped to the balance cock and a narrow bar-shaped nickel collet with a boss on the balance staff.

Going-train counts:
Great wheel (going barrel) 78 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth.

Provenance: Ilbert Collection; purchased by Ilbert from Webster in 1931 (reg. no. CAI-1750).

30 ALBERT H. POTTER

c. 1900

CHRONOMETER *Plates 24a–e, 25a*

Signature: On the barrel bridge 'Albert H. Potter & Co. GENEVA Pat. Oct 11.75'. On the balance cock 'ESCAPEMENT Pat. Oct. 11.75.' On the back plate 'Plate des, $^{\underline{n}}$. Pat. Jan 4.76'. On the centre, third and fourth cocks 'No. 62'.

Case: Later brass case with glazed front and back bezels. Diam. 56·7 mm, th. over glasses 19·1 mm

Dial and hands: Flat enamel canister dial with sunk subsidiary seconds, and with a positioning peg in the edge of the plate, and a corresponding slot in the nickel ring. On the dial 'Albert H. Potter & Co.' Geneva.

Blued steel hands.

See Jules Jurgensen cat. no. 22 for a similar dial and hands.

Movement

Front plate diam. 46·7 and 45·7 mm; front plate th. 7·0 mm; frame h. 8·7 mm.

Frame: A massive disc of nickel brass is deeply hollowed to accommodate the barrel, going train, escapement and balance, top bearings being provided in bridges and cocks. Recesses are also turned on the dial side of the plate for the keyless work, motion work and a detachable plate with the third, fourth and escapement arbor lower bearings. The movement was secured in its case by three screws from under the dial. Each screw passes right through the plate and has a positioning pivot on the other end, presumably to fit into a corresponding hole in the case middle. The central portion of each screw is a boss with a peg set in it, the plate being hollowed to receive them. On turning the screw the peg swings out to contact a fixing block on the inside of the middle of the case.

Going barrel and keyless work: English type of rocking-bar keyless work, hand set operated by a lever. The barrel ratchet wheel with Geneva stop-work and with integal hollow barrel arbor actually pivoting in a hole of large diameter in the main plate. This wheel kept in its recess by three 'tags' which overlap it and are screwed to the plate. The brass great wheel screwed to a collet on an arbor pivoted in jewels in a bridge on the back of the main plate and in the barrel ratchet wheel. The finger of the stop-work carried on a square on the end of the great wheel arbor. The barrel free to turn on the great wheel arbor, its open end towards the main plate. A peg in the closed end of the barrel passes between the spokes of the great wheel and supplies torque by pressing against a spoke. The centre wheel is protected from the open end of the barrel facing towards it, by a disc concentric with the barrel, passing over the centre wheel and secured to the main plate by two screws.

On turning the barrel ratchet wheel in the direction of wind, the inner end of the mainspring is carried round as the spring is wound. The barrel, in trying to turn, applies pressure to the great wheel. Since the stop-work is between the great wheel arbor and the barrel ratchet wheel, winding causes the stop-work to turn in one direction, and the rotation of the great wheel arbor causes it to turn in the other.

The purpose of this apparently complicated and elaborate system is to provide a measure of safety for the going-train in the event of breakage of the mainspring. If the mainspring breaks at or near its inner end when wound, it will fly round inside the barrel until tight against the barrel wall to which it will transfer its momentum. The barrel will turn violently backwards and presumably the peg will be sheared off against a spoke of the great wheel. The system, in an improved state, was later used by the Waltham Watch Company. Its disadvantage in this example is that the going-train is not completely protected, and the extra height needed to lodge all the parts is considerable. There is evidence that some other coupling between great wheel and barrel existed, a sink and a screw hole remain in the barrel wall, and a steel pin which has sheared off. Another advantage is that the great wheel with only one pivot on the end of the arbor where it is mounted stands more chance of being true. Also, the pivots are of a much smaller diameter, thus reducing frictional losses.

Going train: Conventional train with very high numbered pinions, the brass wheels electro-gilded to a whitish finish. The leaves and ends of the pinions left smooth but not polished. The undercuts carefully turned, the arbors dull polished, the pivots and shoulders probably once highly polished. Only the escape pinion has highly polished leaves and ends.

Jewelling: All the pivots of the going train and escapement arbors run in pierced jewels, those of the escapement with endstones. Only the centre arbor lower jewel *bombé*, the other train jewel faces flat against the pivot shoulders.

Escapement: A form of pivoted detent escapement. The steel escape wheel with polished leading edges and tops of the teeth, sunk out on both sides leaving only the ends of the teeth standing to the full thickness. The detent with locking pallet on a separate short arm, a spiral return spring of $4\frac{1}{2}$ turns with a steel stud and collet. The gold passing spring screwed to the end of an arm integral with the main body of the detent, but standing at right angles to it.

The action of the gold passing spring is most unusual. The end of the detent has a slot cut in it, leaving a portion like a pin standing on end. The end of the passing spring is bent around this so that it points towards the balance. The action of unlocking occurs when the passing spring end is pressed towards the peg, causing the detent to move. During the passing action the spring flexes slightly and the end moves away from the peg and into the slot. The radius to the tip of the discharge roller jewel is much greater than usual, being nearly the same as that of the impulse roller.

The steel impulse roller is polished all over and set with a ruby pallet with radial impulse face. The jewelled discharge roller, also of polished steel, with two flats for setting, is mounted between the impulse roller and the balance.

Balance: Possibly a Guillaume bimetallic balance of nickel steel and brass, with steel quarter screws and gold compensation screws. The bimetallic rims unusually high. Diam. of rim 16·8 mm, h. 2·44 mm.

Balance spring: Blued steel helical spring of 11 turns with terminal curves, free sprung to a steel stud on the edge of the balance cock and a bar shaped polished steel collet.

Going-train counts:

Great wheel 108 teeth, 5 arms

Centre pinion 18 leaves, wheel 104 teeth, 5 arms
Third pinion 13 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 100 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth.

Keyless work:
Pendant bevel wheel 24 teeth
Central rocking-bar wheel 42 teeth
Intermediate winding wheel 34 teeth
Intermediate hand-set wheel 23 teeth
Second intermediate hand-set wheel 19 teeth
Barrel ratchet wheel 72 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1834).

Note: An English patent, No. 2985, was taken out in 1875 by a patent agent, W. R. Lake, on behalf of Albert Henry Potter of Chicago, Illinois, USA. Among the inventions included for protection are:

a) An exceptionally thick watch movement front plate to provide greater rigidity and more effective dust exclusion.
b) A continuous auxilliary compensation balance somewhat similar to one of Dent's.
c) A safety mainspring barrel to protect the watch in the event of mainspring breakage.
d) A pivoted detent escapement designed to reduce the angle through which the balance must move in order to unlock the escapement, thus reducing the risk of 'setting' or stopping in wear.

With the exception of the balance, all these inventions are included in this watch.

Bibliography: *The American Horologist*, September 1941, p. 36.

31 MAKER UNKNOWN, probably MAISONETTE and therefore Swiss

c. 1905

CHRONOMETER MOVEMENT *Plate 25b–e*

Dial and hands: Flat enamel dial with the central portion and the subsidiary seconds sunk, attached by two feet passing into holes in the front plate, with screws accessible from the edge of the plate. A reserve of going indication in the upper part of the sunk central part of the dial.

Blued steel hands.

Movement:
Ebauche marks in a lozenge-shaped cartouche, FJ and G and elsewhere on the dial side of the front plate 5224 and 18.

Front plate diam. 45·3 mm; back plate diam. 43·0 mm; frame h. 8·7 mm.

Frame: A type of three-quarter plate construction, the back plate made from the solid and relieved on the underside to accommodate the mobiles, and secured by three screws and three steady pins. The movement was secured in its case by a single dog screw and a positioning peg in the edge of the front plate. All the brass parts electro-gilded a whitish colour. Marked on the top plate 'Chronometer No 48486'.

Going barrel and keyless work: A normal going barrel fitted with four-turn Geneva stop-work on the cover end. Typical Swiss sliding-pinion keyless work with hand-set operated by a touch-piece projecting from the edge of the front plate under the dial near the pendant.

Going train: Typical layout and construction, the brass wheels gilded like the frame, the steel pinions and arbors polished.

Jewelling: The rear centre pivot and those of the third, fourth and escapement arbors in pierced jewels, those of the balance staff with endstones. The train jewels on the back plate appear to be garnet. They are in base metal settings secured by screws.

Escapement: Pivoted detent escapement, the gilded brass escape wheel left the full thickness and locked by the second tooth after the one which has just given impulse. The detent set with a half-round locking jewel extending into a banking hole in the front plate. The gold passing spring held with a screw to the arbor boss and extending into a slot in the front plate behind the detent to act as the return spring. The detent horn formed at right angles to the detent itself, and holding the passing spring clear except of the locking stone boss (see cat. no. 29 for a similar arrangement). The impulse roller of polished steel, and set with an impulse pallet with its impulse face on a radial. The discharge roller a later replacement crudely made of steel. The detent planted with its pivoting axis well outside a tangent to the locked tooth, and lying on a centre line from the balance centre to the locked tooth.

Balance: Bimetallic two-armed balance with brass screws. Diam. of rim 15·5 mm, h. 1·38 mm.

Balance spring: Blued steel helical spring of $7\frac{1}{2}$ turns, with terminal curves, pinned to a brass stud clamped under a steel plate on the balance cock and to a round brass collet. The index on the balance cock fitted with a fine adjustment for regulation, operated by a screw.

Up-and-down indicator: A planar differential is fitted between the barrel ratchet wheel A and a brass wheel fitted on the barrel cover B. A meshes with a steel wheel C pivoted on a shoulder screw, and itself meshing with a smaller steel wheel D on a main arbor passing through the frame. The front plate has a turned sink on the dial side to accommodate a brass wheel E in mesh with B. E pivots freely on the main arbor coming through from the back and is held, with a little shake, by a steel wheel F pushed tight on the main arbor. F meshes with another, G, mounted on a pinion H, turning on a shoulder screw, on the loose brass wheel E.

On turning the winding button to wind the watch, A turns to wind the spring, and turns with it C and D, and F on the other end of the main arbor. F then drives G carrying H which in turn drives J. J is a brass wheel mounted on a pinion K fitting freely on a cannon integral with F. K is in mesh with the large crossed out wheel L carrying the indicator hand and having a pivot passing into the front plate.

During the running of the watch B turns driving E. This results in G and H being carried round F and J with which they are in mesh. This differential motion causes J to turn the opposite way to winding so that K and L turn backwards also. The numbers of teeth are chosen so that one turn of A causes J to advance by one turn, which it will return on one turn of B.

The counts of the wheels are:

A is a steel wheel of 44 teeth
B is a brass wheel of 80 teeth
C is a steel wheel of 20 teeth
D is a steel wheel of 11 teeth
E is a brass wheel of 60 teeth
F is a steel wheel of 18 teeth
G is a steel wheel of 18 teeth
H is a steel pinion of 10 leaves
J is a brass wheel of 40 teeth
K is a steel pinion of 12 leaves
L is a brass wheel of 96 teeth

Going-train counts:
Great wheel (going barrel) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 30 teeth

Keyless work:
Crown wheel 11 ratchet 20 spur teeth
Castle wheel 11 ratchet 22 contrate teeth
Intermediate winding wheel 41 spur teeth
Intermediate hand set wheel 41 spur teeth

Provenance: Purchased 1972 (reg. no. 1972, 4-5, 1).

II. iii (cat. nos 32–51)

THE INVENTION OF JOHN ARNOLD'S SPRING DETENT ESCAPEMENT AND ITS USE BY JOHN AND JOHN ROGER ARNOLD

In 1781 or 1782 John Arnold made his first spring detent watches. He could easily have made his pivoted detent into a spring detent by mounting it on a spring instead of on a pivoted arbor, which is what Earnshaw did. Arnold, however, did not feel this was right since the necessarily delicate spring would then have been in compression. Consequently he completely redesigned the escapement, as shown in figs 3 and 3a. As can be seen, the spring A is now in tension, with the locking stone B acting on the bottom of the curved impulse face of the escape wheel tooth C and the detent unlocking inwards, that is towards the escape arbor. In the illustration the escape wheel turns clockwise with the curved face of the tooth acting with the impulse jewel D, which is set radially. The unlocking or discharge jewel E acts with a spring F which is sometimes gold, sometimes steel. In the twenty examples in this section, five are of gold and ten of steel. G is the stop screw which controls the locked position of the detent.

All but one of this group by John and John Roger Arnold has a fusee; cat. no. 50, one of the two latest chronometers, has a going barrel. There is a progression of balances: Arnold's YZ, OZ, Z, cruciform and some Earnshaw's (see Appendix). Cat. nos 33, 37 and 46 have gold balance springs. The balance in cat. no. 50 has, most unusually, a flat spiral spring without a terminal curve.

32 JOHN ARNOLD AND SON

c. 1790

CHRONOMETER *Plate 26a–d*

Signature: Engraved on the back plate 'John Arnold and Son London Inv^t et Fec^t No 125'.

Case: Later plain silver case with London hallmark for 1790, 1810 or 1830 but probably 1830 and maker's mark GR. Bezels front and back snapping shut on the middle. The movement hinged to the case at 12 o'clock and with a catch opposite. Diam. 58·8 mm, overall h. 26·6 mm.

Dial and hands: Flat enamel dial with short feet pinned directly to the front plate of the movement, no dial plate. The dial signed ARNOLD & SON LONDON and numbered 225.

Pale yellow gold minute and hour hands, blued steel seconds hand, probably all replacements.

Movement
No dial plate. Front plate diam. 51·0 mm; back plate diam. 48·1 mm; frame h. 11·9 mm.

Frame: Full plate (gilded brass) with four turned pillars, the back plate retained by pins. The bearings for the pivots of the going train are now brass bushes let into the plates and retained by blued steel screws but were probably originally in jewels. The movement hinge riveted directly to the front plate under the dial. The case catch held by a shoulder screw on the inside of the front plate, its return spring a later replacement passing over the holes for the original maintaining detent spring.

Fusee: Keywound and provided with the usual stop-work and maintaining power, the maintaining ratchet wheel brass. Blued steel maintaining detent pivoted in the frame well in from the edge, with a return spring set in a screw in the top plate, a later replacement of a spring originally screwed to the inside of the front plate. The stop piece return spring fixed to the stop piece itself.

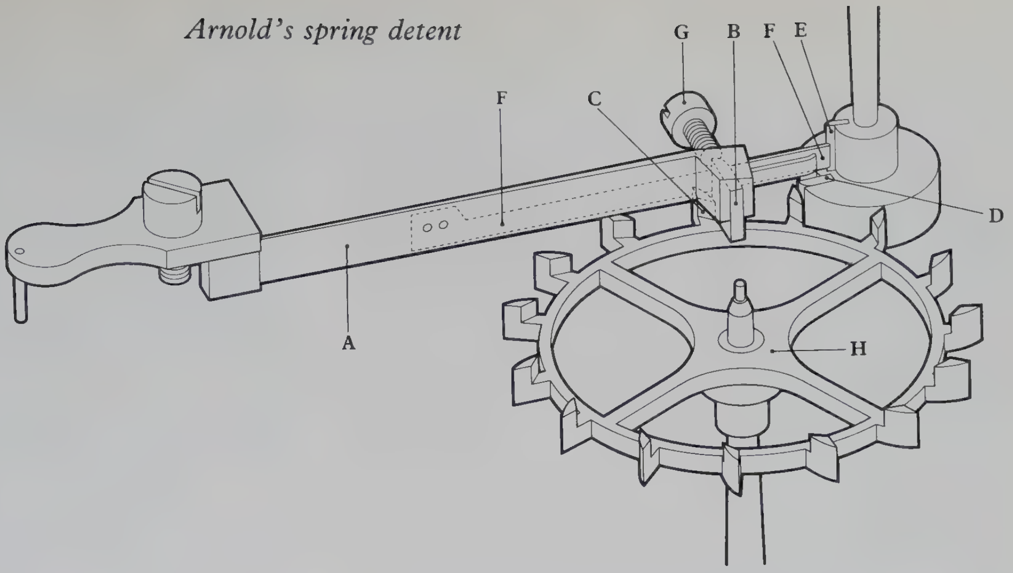


FIGURE 3
John Arnold's spring detent escapement

A	detent
B	locking stone
C	escape wheel tooth
D	impulse jewel
E	discharge jewel
F	passing spring
G	banking screw
H	escape wheel

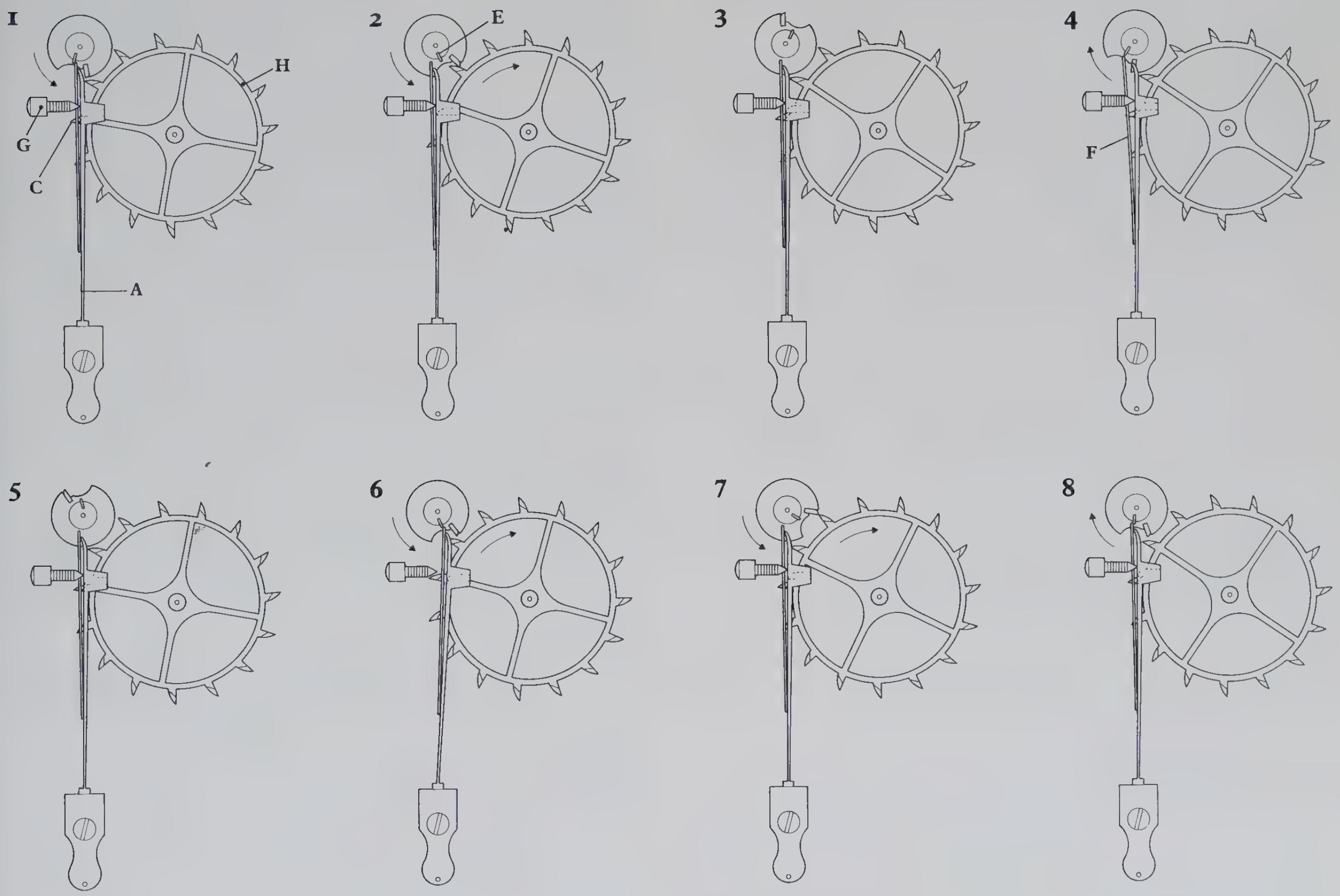


FIGURE 3A
Sequence of operations of John Arnold's spring detent escapement

1 Commencement of unlocking. Discharge jewel E has connected with passing spring F which in this direction of action can be considered as solid with detent A which is thus being moved aside
2 Detent locking stone B has moved out of engagement with escape wheel tooth C. Escape wheel H is moving forward and giving impulse to balance via impulse jewel D
3 Impulse has been completed and escape wheel H is once again locked on detent A
4 Balance has reversed its direction and is passing detent without affecting its position. This is because in this direction passing spring as presented to discharge jewel is long and weak
5 Balance has reached maximum excursion in anticlockwise direction and is just about to reverse again
6 Escape wheel is once again unlocked and balance about to be impulsed
7 End of impulse
8 Balance just about to pick up passing spring again

Going train: Going-train wheels gilded brass, pinions well finished and polished.

Jewelling: Only the escapement pivots now run in pierced jewels with endstones. The escapement having a jewelled locking stone on the detent and a normal jewelled discharge pallet, but the impulse roller made from a solid piece of clear sapphire.

Escapement: Arnold spring detent escapement with brass escape wheel, the locking corners of the teeth damaged. The detent probably not original; the top of the foot polished, the rest left grey. Gold passing spring riveted on. The detent banking against a screw set in the back plate.

Barrel: Large barrel with flange at the top plate end. The setting-up-work mounted under the dial plate.

Balance: Later Pennington-type replacement. The bimetallic rims made separately from the crossbar of brass, and secured to this by screws. Steel quarter and compensation screws with special split collar friction device. Diam. of rim 20·5 mm, h. 2.75 mm.

Balance spring: Later helical balance spring, the upper end secured to a brass stud on the balance cock, long rectangular brass collet.

Balance cock: Finely pierced and engraved decoration of gryphons and acanthus leaves. At some time the cock has been broken between the gryphon and the end with the stud and balance upper bearing; the repair crudely executed with soft solder.

Going-train counts:
Great wheel (fusee) 60
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, hour wheel 42 leaves
Minute pinion 14 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1841).

33 JOHN ARNOLD AND SON
1790

MARINE CHRONOMETER[1] *Plates 26e–f, 27a–b*

Signature: On the back plate 'John Arnold and Son London No 14/104 Inv^{t} et Fec^{t}.' On the dial: 'John Arnold and Son London, No. 14'.

Box: The movement contained in an octagonal mahogany box with a hinged glazed lid, and with a lock to secure the lid. The box has at some time been suspended in gimbals, the brass pivoting pieces remaining on the outside of the box. The winding hole in the bottom is brass lined and protected by a rotatable escutcheon plate with eccentric hole for the key, and without a return spring. The brass lining tube is part of a plate fitted on the inside of the box, and having a similar tube projecting upwards on the inside. This is covered by a sliding brass cap on the winding square.[2] Box across the flats 160 mm, overall h. 101 mm.

Dial and hands: The dial of silvered engraved brass attached by three screws on the edge to the front plate. The seconds hole in the dial bushed.

Blued steel hands, the minute hand held by a screw in its boss to a square on the cannon pinion, and with a pinned collet. The seconds hand screwed to its pipe having a blind hole.

Movement
Front plate diam. 118·5 mm, reduced to 106·5 mm; frame h. overall 37·0 mm; back plate diam. 101·7 mm.

Frame: Full plate construction built up on a massive front plate double recessed under the dial. Four turned pillars, the back plate held by recessed blued steel screws, the screws no longer have their distinguishing dots. The balance potance with a moulded edge to the foot. The brass parts decorated with spotting applied by hand. The movement held in the box in a similar way to cat. no. 34.

Fusee: Fitted with Harrison's maintaining power and pivoted in detachable flanged bushes in the frame. On the winding square is fitted a brass dust-excluding cap able to slide a short distance up and down on the square, held by a pin passing into rectangular holes. The inside of the great wheel signed 'John Glover December 4th 1790'. Setting-up-work fitted on the inside of the front plate under the end of the barrel. The arbor with an extended square for setting up on the back plate end. The barrel waisted on the closed end to clear the teeth of the great wheel. The tapered mainspring hooked with an eye on a steel hook set in the barrel wall, and to a steel hook passing through the snailed brass boss and the steel barrel arbor. The maintaining detent pivot in the back plate is in a detachable bush held with a single screw. If this bush is removed, the detent can be removed from the assembled frame.

Going train: The usual design and layout. The centre and third wheels riveted to their pinions, the fourth and escape mounted on brass collets. The ends of the pinions and the arbors and pivots polished.

Jewelling: All the pivots of the going train arbors run in pierced jewels except those of the fusee arbor. On the back plate all the jewel settings include an endstone. Endstones also fitted for both escape pinion arbor and balance staff pivots, that in the balance cock a diamond.

Escapement: Arnold spring detent escapement, the teeth of the brass escape wheel notched on their acting cycloidal faces as a result of wear on the corner of the impulse jewel. The detent planted very near the fusee bearing, its retaining screw in a bush and fitted with a steel passing spring held by two rivets. Banking for the detent provided by a brass screw set in a slot near the edge of the detent slot. Both impulse and discharge rollers jewelled, also the detent.

Balance: John Arnold 'YZ' balance. Three short bimetallic segments screwed to brass arms radiating from a boss screwed to a collet on the balance staff. The bimetallic sections consist of an inner rim of platinum and an outer rim of an alloy of silver, copper and zinc. Diam. of rim 55·0 mm, h. 5·5 mm.

Balance spring: Free sprung gold helical spring of $7\frac{1}{2}$ turns, with terminal curves, undersprung, being between the balance and the back plate so as to take some of the weight of the balance off the lower staff pivot when the chronometer is in the dial up position. The collet a rectangular block with square hole and pin for the spring. The stud passing through a slot in the back plate and screwed and steady pinned to the foot of the balance potance. It is fitted with an adjustable clamp to grip the spring.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 80 teeth, 4 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves (brass)
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert collection; Ilbert records in his inventory notebook that he purchased this chronometer from Malcolm Gardner in 1932. He also records the report by Jauncey mentioned below and that 'In USA No 26/116 has John J. Glover July 30 1791 but this alleged John Arnold. Arnold and Son 13/122 has inscription on dial presented to Capt Dundas etc 1792'. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-2069).

Notes

1. This chronometer accompanied Captain Vancouver on his expeditions around the world; it accompanied, amongst others, Arnold 176 to which it is very similar and which is now in the Vancouver Maritime Museum, Canada.

2. Inside the box is a note in C. A. Ilbert's handwriting: 'Jauncey reports that his Arnold and Son 30/120 in similar box, similar balance, spring and everything practically has Thomas Prest Sept 26th 1791 scratched on fusee.' (Britten 1982, Thomas Prest, Foreman to J. R. Arnold, died 1855.)

Bibliography: Capt. Vancouver, *A Voyage of Discovery to the North Pacific Ocean and Round the World under the command of Captain George Vancouver*, London, 1798 (3 vols).

34 JOHN ARNOLD AND SON

c. 1790[1]

MARINE CHRONOMETER *Plate 27c–f*

Signature: On the back plate 'John Arnold and Son London No 26 Inv^{t} et Fecit'. On the dial 'John Arnold London No 26'.

Box: For box details see cat. no. 33. Box across the flats 162 mm, h. 80 mm.

Dial and hands: Flat enamel dial, cracked, secured to the front plate by three feet and pins. Faintly marked in red in the enamel of the back 26, and also marked 'No 26'.

Blued steel hands, the minute hand held by a screw in its boss to a square on the cannon pinion. The seconds hand screwed to a pipe having a blind hole.

Movement
Front plate diam. 121·3 mm, reduced to 112·3 mm; back plate diam. 94·4 mm; frame h. 33·0 mm.

Frame: Full plate construction built up on a massive front plate double recessed under the dial. Four turned pillars, the back plate held by recessed blued steel screws. The balance potance without the usual moulded edge to its foot. The movement held by the front plate, adjusted into a hole in an octagonal wooden board fitting into a rebate in the box. The front plate is secured to the board by three screws passing through from the back into the flange of the front plate resting on the front of the board. The brass parts finished smooth and with a scratchy polish but not decorated.

Fusee: Fitted with Harrison's maintaining power, the ratchet wheel brass and planted in bushes standing proud of both front and back plate. On the winding square is fitted a large brass dust-excluding cup. There is no signature anywhere on the inside of the fusee or great wheel parts, the number 26 is scratched on the inside of the great wheel under the brass maintaining spring, the latter is probably a replacement. Setting-up-work is fitted on the inside of the front plate, under the end of the barrel. There is an extended square for setting up on the back plate end of the barrel arbor. The tapered mainspring is hooked with an eye to a steel hook set in the barrel wall, and similarly at the inner end to a hook passing through both the snailed brass boss and the arbor.

Going train: The usual design and layout, the centre, third and fourth wheels riveted to their pinions. The steel arbors and pivots polished, the ends of the pinions, undercuts and rivets left grained.

Jewelling: The pivots of the fourth and escape pinion arbors and those of the balance staff run in pierced jewels. Endstones are fitted for both balance staff and escape pinion bearings, and the fourth rear bearing. A very small diamond endstone set in a blued steel ring is fitted in a deep recess in the balance cock. The jewel assemblies with endstones are not made to hold oil between the endstone and the jewel except for the pierced jewels for the balance staff pivots which have curved oil retaining sinks on both sides. The fourth lower jewel resembles and works as on ordinary train jewel, the end of the pivot resting on the endstone instead of the shoulder on the pierced jewel. The pierced jewel for the escape pinion arbor back plate pivot is flat on both sides and has no means of retaining oil, but that in the front plate resembles those for the balance staff.

The jewel settings themselves are brass discs adjusted into sinks in the plates, only the fourth pierced jewel settings are double sunk.

Escapement: Arnold spring detent escapement, the teeth of the brass escape wheel notched on their acting cycloidal faces as a result of wear on the corner of the impulse jewel. The detent fitted with a later brass passing spring. Both rollers and the detent are jewelled. Banking for the detent provided against a brass screw set in a slot in the back plate on the edge of the detent slot.

Balance: Bimetallic 'z' type balance, the two short steel and brass rims attached by brackets to the steel crossbar. The central boss is secured by two screws to a brass boss on the balance staff. Notches for poising have been filed in the underside of one of the arms, near the outer end. Timing screws are set in the rims at the ends of the arms, and a tapped hole is provided near the free end of each rim. The compensation can be adjusted by turned and slotted brass nuts on threaded pieces integral with the free ends of the rims. The steel parts of the rim have been blued. Diam. of rim 47·4 mm, h. 3.0 mm.

Balance spring: Blued steel helical spring of $6\frac{3}{4}$ turns, with terminal curves, pinned with a square peg in a square hole in the steel poised collet. The other end of the spring is clamped by a screw and plate to a steel bar, itself screwed to the end of a brass piece like an index on the top of the balance cock. These clamping and fixing arrangements are to position accurately and to centre the spring. The long tail on the brass piece like an index is presumably to enable fine adjustment to be made for beat, or for resetting up to be accurately carried out if the spring is disturbed as, for instance, during cleaning. Normally the whole system is held tightly clamped by screws, but the massive balance cock would permit the various screws to be released and tightened without pinching the pivots of the balance staff.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 80 teeth, 4 arms
Escape pinion 10, leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves.
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert collection; Ilbert purchased this chronometer from Malcolm Gardner in 1932 (reg. no. CAI-1952). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Note

1. Ilbert mentions that Arnold No. 35 is dated 1785 and John Arnold and Son No. 492 is dated 1793.

Bibliography: Britten, 1982, 9th edn, pp. 220, 221, pl. 138a and b.

35 JOHN ARNOLD AND SON
1787–1799

CHRONOMETER MOVEMENT *Plate 28a–b*

Signature: Engraved on the back plate 'John Arnold and Son London Inv.^{t} et Fecit No $\frac{186}{487}$'.

Dial and hands: Missing, but see cat. no. 37.

Movement
No dial plate (the dial was fixed directly to the front plate). Front plate diam. 42·8 mm; back plate diam. 40·0 mm; frame h. 9·7 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, gilded brass. The case push-piece and spring once fitted between the plates on the front plate are both missing. The hinge to attach the movement to its case on the dial side of the front plate also removed. There is evidence that the watch was once fitted into a replacement case, in the form of case screws which have been fitted to the front plate.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass. The return spring for the maintaining detent a fine wire set in a screw in the back plate, the wire now broken.

Barrel: With flange at the top and relieved at the bottom to clear the great wheel, the arbor squared at both ends. Setting-up-work on the front plate under the dial, the ratchet with an integral spring now broken.

Going train: Wheels of gilded brass, the pinions of polished steel nicely finished. The teeth of the third and fourth wheels particularly thin. Rather low numbers of teeth in the wheels and pinions.

Jewelling: Only the escapement pivots in jewelled holes with endstone jewels. In the balance cock a diamond endstone set in a blued steel plate, not original, the other endstone ruby. The impulse and discharge rollers and the detent jewelled.

Escapement: Arnold spring detent escapement with brass escape wheel, the curved impulse faces of the teeth slightly marked. The detent with polished top to the foot, and with a steel passing spring riveted on, banking against a screw set in the back plate.

Balance: Made up of a polished steel wheel with three arms and two bimetallic rims screwed on with brackets diametrically opposite each other. The bimetallic rims blued steel on the inside, brass on the outside. A gold pin in the steel rim possibly for poising. This type of balance is known as 'OZ'.

The amount of compensation can be adjusted by turning the brass weights on the threaded portions at the free ends of the rims thus moving them towards the ends to increase, or away from the ends to decrease, the amount of compensation. Two steel timing screws set radially, one in each bimetallic rim above the fixing bracket. Diam. 19·8 mm, h. 2.0 mm.

Balance spring: Blued steel helical spring of 7 turns with terminal curves at each end. The upper one pinned to a blued steel stud screwed to the balance cock, the stud brass with round hole and D-shaped pin.

Balance cock: Finely pierced and engraved.

Going-train counts:
Great wheel (fusee) 60
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 60 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work: Missing.

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1936 (reg. no. CAI-1576).

36 JOHN ARNOLD AND SON

1787–1799

CHRONOMETER MOVEMENT *Plates 28c–f, 29a–c*

Signature: 'John Arnold & Son London Inv^{t} et Fec^{t} No. $\frac{298}{599}$'.

Dial and hands: The enamel dial which is chipped is not original but was possibly made specially, the back is marked 'A & D' – so possibly by Arnold & Dent. Under the dial is scratched 'F.B^{y} 1816'. There is no dial plate, but the front plate is turned to resemble a normal dial plate at the edge. The dial is secured by three feet and pins to the front plate.

Gold hour and steel seconds hands. Minute hand a replacement.

Movement

Compare the movement with cat. no. 35.

Front plate diam. 43·0 mm; back plate diam. 40·0 mm; frame h. 10·0 mm.

Frame: Similar to cat. no. 35, but the case catch and spring and the hinge are still in place.

Barrel: Flanged at top, arbor squared both ends.

Fusee: Similar to cat. no. 35.

Going train: Similar to cat. no. 35.

Jewelling: The pivots of the fourth wheel and the escapement in pierced jewels. The escapement with endstones, a diamond in blued steel setting on the balance cock. The impulse and discharge rollers and the detent, jewelled.

Escapement: Arnold spring detent, see cat. no. 35. The top of the detent foot not polished, the passing spring of steel held with two rivets.

Balance: 'OZ' balance made up as in cat. no. 35, but on a brass three-armed wheel having one small platinum poising screw set in the rim. Diam. 23·6 mm, h. 2·7 mm.

Balance spring: Gold helical spring of $4\frac{1}{2}$ wide turns with terminal curves at each end, the upper one pinned to a blued steel stud screwed to the balance cock. Stud and collet both of steel with square holes.

Balance cock: Compare with cat. no. 35.

Going-train counts: As cat. no. 35.

Motion work:
- Cannon pinion 10 leaves (not waisted and not retained by a pin), minute pinion 12 leaves
- Minute wheel 40 teeth gilded brass, hour wheel 36 teeth gilded brass

Provenance: Ilbert Collection (reg. no. CAI–1577).

37 JOHN ARNOLD AND SON

1787–1799 (No $\frac{327}{628}$ has the hallmark for 1786)

CHRONOMETER MOVEMENT *Plates 29d–e, 30a–b*

Signature: 'John Arnold & Son London Inv.^{t} et Fec.^{t} No $\frac{358}{659}$'.

Dial and hands: The dial secured directly to the front plate of the movement by three feet and pins. The front plate turned to resemble a dial plate, and recessed to protect the edge of the dial. The dial numbered 358. On the back fired in red very faint N 358.

Red gold 'beetle and poker' hands, and gold seconds hand.

Movement

Similar to cat. nos 35, 36. Front plate diam. 43·7 mm; back plate diam. 40·4 mm; frame h. 10·4 mm.

Frame: Similar to cat. nos 35, 36.

Fusee: Similar to cat. nos 35, 36.

Going train: Similar to cat. nos 35, 36.

Jewelling: Similar to cat. nos 35 and 36. The impulse roller not jewelled, but the impulse face polished.

Escapement: Similar to cat. nos 35 and 36. The detent a later replacement, with a rectangular foot, and the empty steady pin hole of the original detent still visible. The escape wheel teeth are marked on the impulse surfaces in two distinct places, indicating that the adjustment of the escapement was different with the replacement detent.

Balance: 'OZ' balance similar to cat. no. 35 with the addition of two steel screws set radially in the compensating rims near the compensation screws, to aid in poising, also the outer metal in the rims is a silver brass. One of the compensation screws has a ring turned in it, presumably also for poising. A small gold pin is set standing up from the rim near one compensating screw as in cat. no. 35. Diam. 25·0 mm, h. 2·3 mm.

Balance spring: Gold helical spring of 5 turns now distorted, with terminal curves, pinned to a blued steel collet and stud on the balance cock, both with square holes.

Going-train counts: As cat. nos 35, 36.

Motion work: As cat. no. 36.

Provenance: Ilbert Collection (reg. no. CAI–1578).

Note: The mainspring although broken is apparently original. H. 4·72 mm, th. 0·22 mm. Inside diam. of barrel 17·4 mm; available h. inside barrel 4·94 mm.

The mainspring is signed, but very indistinctly, the inscription could be 'May 4 14 Arnold'.

38 JOHN ARNOLD AND SON

1787–1799. A similar movement, 14/1014, has the hallmark for 1795.

CHRONOMETER MOVEMENT *Plate 30c–d*

Signature: 'John Arnold & Son Inv^{t} et Fec^{t} No ^{17}/1017'.

Dial and hands: Enamel dial secured as in cat. nos 35 and 37. Minute dots and instead of hour numerals the letters making up the name 'SIBELLA M^{C}LEAN', the N now missing due to damage of the dial, also the number 17 in the upper half. No subsidiary seconds dial. This dial is presumably a replacement.

The hands missing.

Movement
Similar to cat. nos 35 and 37. One of a new series with a detachable barrel bridge.

Front plate diam. 43·4 mm; back plate diam. 40·8 mm; frame h. 9·5 mm.

Frame: Similar to cat. nos 35 and 37, but with detachable barrel bridge. The case hinge removed.

Fusee: Keywind fusee fitted with stop-work and maintaining power. Brass maintaining ratchet wheel, blued steel maintaining detent pivoted between the plates. The return spring for the maintaining detent a piece of polished steel wire set in a blued screw in the back plate. Setting-up ratchet and click under the dial, on the front plate, the ratchet wheel pinned to the extended square of the barrel arbor. The click originally with an integral spring now broken. The barrel arbor extended with squares on both ends. The upper end protruding through the barrel bridge for setting-up purposes. The square is exceedingly small – only 0·8 mm across flats.

Going train: Similar to cat. nos 35 and 37, but with a fourth wheel of 80 and escape pinion of 8. The fourth pivot on the dial side shows clear signs of having been shortened.

Jewelling: The escapement pivots only in jewelled bearings with endstones, the endstone on the balance cock a diamond. The remainder of the going-train pivots running in plain holes in the plates. The impulse roller not jewelled, the unlocking jewel let into and standing up from the discharge roller. The detent with jewelled locking stone.

Escapement: Similar to cat. nos 35 and 37, pronounced marking of the impulse surfaces of the escape wheel teeth. Grey steel detent with polished top to foot. The gold passing spring screwed on top and the detent horn bent up to meet it. Probably a replacement detent. The edge of the impulse roller polished, the top and bottom left grey.

Balance: Known as the 'z' balance because of its shape. A single steel crossbar has two bimetallic rims fixed one at each end by brackets and screws. Timing screws are fitted radially into the rims at the ends of the crossbar. Holes are also drilled in the rims near their free ends, just before the compensation adjustment screws, for additional poising screws. These are both missing in this example. The fixing brackets mentioned above are integral with each bimetallic rim, each one is screwed and steady pinned to the crossbar. The bimetallic rims are composed of a silver-brass alloy (35% silver) on blued steel. Fitted on the balance staff level with the upper terminal curve of the balance spring is a recessed brass disc, possibly as an amplitude limiting device. If the balance amplitude becomes too great, the terminal curve could be made to touch the edge of the disc, this producing a braking effect. As fitted at present this does not appear to happen. Diam. 21·0 mm, h. 2·2 mm.

Balance spring: Gold (about 18 carat) helical balance spring of 5 turns with terminal curves at each end. Both the collet on the balance staff and the stud on the balance cock are of blued steel, and the spring is secured by one end to each with square steel pins in square holes.

Going-train counts:
Great wheel (fusee) 60
Centre pinion 12 leaves, wheel 64 teeth, solid gilded
Third pinion 8 leaves, wheel 60 teeth, 4 arms gilded
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms gilded
Escape pinion 8 leaves, wheel 15 teeth, 4 arms gilded
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves with turned waist and snap (probably later), minute pinion 14 leaves adjusted onto a tube integral with the minute wheel
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection (reg. no. CAI–1579).

39 JOHN ARNOLD AND SON
1796

MARINE CHRONOMETER *Plates 30e–f, 31a–b*

Signature: On the raised part of the barrel bridge 'John Arnold and Son London No 106/196 Inv^{t} et Fec^{t}'. On the dial 'Arnold & Son London No 106'.

Box: The movement contained in a brass bowl with threaded glazed bezel, gimballed in a large plain mahogany box with carrying handles, a brass escutcheon plate for the lock and an inset ivory disc. These are all later substitutions, possibly for an octagonal box similar to cat. no. 43. Box 245·0 mm square, h. 187 mm.

Dial and hands: Later engraved silvered brass dial, the engraving filled with black wax, fixed in a recess in the dial plate by three screws in the edge, from the front.

Gold minute, hour and up-and-down hands, blued steel seconds hand. There was once a collet and pin to secure the cannon pinion.

Movement
Dial plate diam. 135·2 mm; front plate diam. 118·0 mm (reduced to 105·0 mm); back plate diam. 102·7 mm; frame h. 38·4 mm.

Frame: Full plate construction with a high detachable barrel bridge. Four turned pillars, the back plate retained by blued steel screws, each with a turned brass washer. The new dial plate is secured to the underside of the front plate flange by three screws also from the underside. The tapped holes remain in the edge of the front plate for the original dial (see also cat. no. 43).

Fusee: Fitted with Harrison's maintaining power with a brass wheel and the usual stop-work, the brass block for the stop-piece riveted to the back plate. The original sliding dust-excluding cap remains on the winding square (see also cat. no. 33).

This would have worked in conjunction with the brass plate and upstanding tube in the original wooden box. It has no purpose in the present brass box, in which the winding hole is protected by an escutcheon plate with spring return, since it cannot reach the bottom of the inside of the box. The inside of the great wheel signed under the maintaining spring 'T. Prest Jan 1796'.

Setting-up-work for the mainspring is planted on the top of the barrel bridge. There is a brass peg to prevent the click overiding the return spring. The barrel is higher than the height of the frame, the bearing for the arbor being carried in the large detachable barrel bridge. The mainspring is not tapered, it is hooked at its outer end by an eye to a steel hook set in the barrel wall, and similarly at the inner end to the arbor which has a snailed brass boss, the hooking passing through both boss and arbor.

Going train: The centre and third wheels riveted to their pinions, the fourth and escape wheels mounted on brass collets. The pinions and arbors polished all over except the undercuts. The escape pinion arbor is pivoted in the plates.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels. Although the fourth pierced jewel in the back plate is a typical train jewel, an endstone is fitted on which the end of the pivot bears. The jewelling for the pivots of the escapement employs pierced jewels with sinks on their convex sides towards the endstones which they appear to touch. The arrangement of the brass settings is as found in nineteenth-century English work. A diamond endstone is fitted on the balance cock.

Escapement: Arnold spring detent escapement, the acting cycloidal faces of the brass escape wheel teeth have been filed and distorted. The detent is fitted with a later gold passing spring held by a single rivet and a later steel locking 'stone' and has been replanted. The impulse roller is similar to that for an Earnshaw escapement, with a radial impulse jewel. The discharge roller is jewelled and provided with an adjusting flat.

Balance: Cruciform balance with a single brass crossbar having a central boss screwed to a collet on the balance staff. At the ends of the arms integral brass blocks projecting downwards carry straight bimetallic strips parallel with the crossbar. At the free ends of these, rods pointing radially outwards carry adjustable nuts. The bimetallic strips appear to be made of steel and a non-ferrous base metal alloy. The fixed end of each bimetallic strip consists of a short section of steel standing at right angles to the strip and secured by a single screw to the brass block on the crossbar. Turned timing nuts are carried on studs also set in the blocks on the ends of the crossbar. Diam. of rim 43·2 mm, h. 5·8 mm.

Balance spring: Blued steel helical spring of 7½ turns, with terminal curves. The brass collet is provided with a square hole and pin to clamp the spring. The stud, screwed and steady pinned to the back plate, has an adjustable plate with a clamp for the end of the spring, the clamp being arranged to grip the spring concentric with the terminal curve.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 80 teeth, 4 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves (brass)
Hour wheel 42 teeth, minute wheel 48 teeth (raised slightly by a brass washer at the end of the cannon pinion).

Up-and-down work: This appears to be a later addition, probably when the new box and dial were fitted. A pinion of 10 leaves drives a wheel of 90 teeth via an intermediate wheel of the same number of teeth.

Provenance: Ilbert Collection; Ilbert appears to have acquired this chronometer in October 1936 from Radley (reg. no. CAI-1948). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Bibliography: For a similar type of balance by F. Berthoud see Rees, *Cyclopedia*, *Clocks*, *Watches and Chronometers*, reprint, 1970, Newton Abbot, p. 150 and fig. 9, pl. XXIX.

40 JOHN ROGER ARNOLD

c. 1800

CHRONOMETER MOVEMENT *Plate 31c–d*

Signature: 'Jn° R Arnold London Inv$^{t.}$ et Fecit No 1761'.

Dial and hands: The dial and dial plate are replacements. The continental-style dial inscribed CHRONOMETER and on the underside marked with the letter W. Secured by short feet and pins to the dial plate, the dial plate with four feet passing through holes in the front plate and secured by pins.

The hour and minute hands are replacements. The seconds hand missing.

Movement

For similar movements see cat. nos 39 and 44, but again a new series.

Dial plate diam. 46·5 mm; front plate diam. 42·3 mm; back plate diam. 40·5 mm; frame h. 7·6 mm.

Frame: Similar to cat. no. 38, but with reduced thickness between the plates. Full plate construction with detachable barrel bridge. Four turned pillars the back plate retained by pins. The brass parts gilded. The case catch and spring fitted on the front plate under the dial, opposite the hinge on the dial plate at 12 o'clock. The balance cock engraved but not pierced.

Fusee: Keywind fusee fitted with the usual stop-work and maintaining power. The maintaining ratchet wheel of brass, the return spring for the maintaining detent a short piece of steel wire set in a screw in the back plate under the detent foot. Setting-up-work on the barrel bridge. The ratchet wheel partly cut away where it would overlap the edge of the bridge.

Going train: Similar train to that in cat. no. 38 except that the great wheel has only 58 teeth instead of 60. The brass train wheels gilded and the fourth pivot on the dial side extended to carry the seconds hands.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones, a diamond on the balance cock. Impulse and discharge rollers and detent also jewelled.

Escapement: Arnold detent escapement with brass escape wheel, the acting surfaces of the teeth slightly out. Grey steel detent, the top of the foot polished, and with a steel passing spring held with two rivets. The detent banking against a small screw set in the back plate.

Balance: 'z' type, similar to cat. no. 38 except that the bimetallic rims do not each have an integral bracket to secure it to the crossbar. Instead, at each end of the crossbar a block is left standing above the plane of the bar, to which a bimetallic rim is secured by two radial screws. The timing screws at the ends of the crossbar pass through clearance holes in the rims and into a slotted hole in each block. Two timing screws at 90° to the bar probably not original. Diam. 18·9 mm, h. 2·55 mm.

Balance spring: Helical blued steel, 7 complete turns and terminal curves at each end. Square section pins used to secure the terminal curves to the collet, and the blued steel stud on the balance cock.

Under the balance cock is screwed a brass shield embracing the coils of the balance spring either as a protection or an amplitude limiting device although the spring cannot touch it now (see also cat. no. 38).

Balance cock: The decoration engraved on the upper surface only, no piercing.

Going-train counts: See entry under 'going train'.

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Arnold and Lewis of Manchester 1931 (reg. no. CAI-1581).

41 JOHN ROGER ARNOLD

c. 1802 (No. 1818 has the hallmark for 1801 and No. 1869 for 1802)

CHRONOMETER MOVEMENT *Plate 31e–f*

Signature: On the back plate, but partly missing as it is cut by the slot for the detent, 'Jn^{o} R Arnold London Inv^{t}. et Fecit No. 1831'.

Dial and hands:
Signature 'ARNOLD 1831' in the upper half. Gold hands.

Movement
For similar movements see cat. nos 40 and 44. On the dial plate scratched 'Arnold 1831' and 'No. 2'.
Dial plate diam. 44·9 mm; front plate diam. 44·1 mm; back plate diam. 40·2 mm; frame h. 7·7 mm.

Frame: Similar to cat. no. 40.

Fusee: Similar to cat. no. 40.

Going train: Similar to cat. no. 40 but the great wheel has 60 teeth instead of 58.

Jewelling: Similar to cat. no. 40.

Escapement: Similar to cat. no. 40.

Balance: Similar to cat. no. 40 but the blocks on the ends of the crossbar finished differently. Diam. 19·8 mm, h. 2·4 mm.

Balance spring: Similar to cat. no. 40 but without the shield or amplitude limiting device under the balance cock. 6 complete turns, with terminal curves.

Balance cock: Compare with cat. nos 40 and 44.

Going-train counts:
Great wheel (fusee) 60
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardener in 1936 (reg. no. CAI-1580).

42 JOHN ROGER ARNOLD

Probably 1804

SURVEY CHRONOMETER *Plate 32a–d*

Signature: On the back plate 'John R. Arnold London Inv^{t}. et Fecit No 217'. On the dial 'Arnold London ONE DAY'.

Box: The movement contained in a drum-shaped mahogany box, 217 numbered in ink on the inside, with a hinged brass bezel having a domed glass. A catch with push-piece is provided to lock the bezel. The inside of the box machined to clear the fusee chain. The winding hole in the bottom of the box is protected by a rotatable circular escutcheon place with an eccentric hole. On the inside is fitted a brass plate with a double-ended tube, one end passing into the winding hole, the other towards the movement. A brass cup is pinned to the winding square, this fits over the brass tube projecting up from the bottom of the box. The side of the box is made from eight segments of mahogany, covered on the outside by mahogany veneer. The bottom is held by eight countersunk brass screws. The box diam. 107 mm, h. 66 mm.

Dial and hands: Engraved silvered brass dial, the figures filled with black wax, with an enamel inset subsidiary seconds dial with the (N^{o}) 217 on it. The hours shown through an aperture at the top of the dial and indicated by an enamel disc jumping forward at the hour. The dial made from a thick brass disc, flanged and deeply recessed on the underside, and adjusted on to the edge of the front plate, where it is held by three screws and a positioning peg. The enamel hour disc is fixed by two feet and steady pins to a brass disc carrying also a jumper wheel. The seconds dial is similarly held in a shallow sink in the front plate, its two feet projecting through to the back.

Blued steel minute and seconds hand, the latter screwed to a blind pipe having a screw head.

Movement:
Dial diam. 92·9 mm; dial th. 6·7 mm; front plate diam. 83 mm; back plate diam. 81·7 mm; frame h. 20·0 mm.

Frame: Full plate construction with detachable barrel bridge and four turned pillars, the back plate with a stoned finish held by four blued steel screws. The balance potance without a moulded outer edge to the foot.

Fusee: Fitted with Harrison's maintaining power, the wheel of brass and the usual stop-work. The blued steel setting-up-work mounted on the barrel bridge and with a spring for the ratchet. The great wheel not signed on the inside or on any other part of the fusee assembly. The barrel arbor with a central snailed brass boss, the inner spring hook passing through both this and the arbor, and its outer end hooked with a blued steel block set in a rectangular hole in the barrel wall. The blued mainspring appears to be original and is signed 'Rob^{t} Clark May 12th 1804'.

Going train: All the train wheels riveted to their pinions, these and their arbors well finished and polished.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones including a diamond endstone in a brass ring in the balance cock. The jewelling is of the usual nineteenth-century English type.

Escapement: Originally an Arnold spring detent escapement but converted to an Earnshaw escapement of very high quality. Banking for the detent provided by the head of a polished brass screw set in a gilded brass piece screwed and pinned to the underside of the back plate. Both rollers polished all over, the impulse roller set with a radial jewel. The detent with straight-grained finish and burnished gold passing spring held with a screw.

Balance: Arnold 'Z' pattern balance but with more screws than is usual, having timing and poising screws. The blued steel and white metal bimetallic rims each held with two screws to upstanding shaped brass blocks on the ends of the crossbar. The balance is secured by two screws to a brass collet on the staff. Diam. of rim 33·75 mm, h. 3·6 mm.

Balance spring: Well made blued steel helical spring of 9½ open coils, with terminal curves probably later, pinned with half-round brass pins to a split brass collet and brass stud. The holes for the spring are also round. There is a screw for sideways adjustment of the diamond-shaped stud on the balance cock.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 14 leaves, wheel 75 teeth no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work: A single tooth on a disc on the cannon arbor indexes a star wheel and jumper carrying the hour disc.

Provenance: According to the Chronometer Ledgers preserved at the National Maritime Museum, Greenwich, no. 217's service with the Royal Navy was as follows:

7th May 1824 *Fury* Capt. Hoppner
7th June 1826 *Success* Capt. J. Stirling
22nd Jan 1834 *Thunder* Capt. W. F. Wise
14th Oct 1864 H.M.S. *Achilles*
10th June 1870 H.M.S. *Resistance*
5th July 1871 H.M.S. *Narsan*
16th March 1872 Dent & Co.
4th July 1892 H.M.S. *Royal Sovereign*
5th Nov 1930 Miss C. Shackleton

Then part of the Ilbert collection (reg. no. CAI-1937). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Exhibited. British Clockmakers Heritage, Science Museum, London, 1952.

43 JOHN R. ARNOLD
1804

MARINE CHRONOMETER (8-day) *Plates 32e–f, 33a*

Signature: on the back plate: 'John R Arnold Inv^{t} et Fecit No 223'. On the dial: 'Arnold London' across the centre and 'No. 223' in the upper part of the second ring.

Box: Octagonal mahogany box similar to those of cat. no. 7 but well-made and finished in polished mahogany veneer. The fittings for a gimbal ring still remain. The edge of the box lid has stringing of a lighter wood. Numbered in ink inside the bottom 223 and EJW 4/98, on paper glued in, 28 October 1813. A key to the lock.

The movement is protected by a brass drum with a glazed brass bezel secured to the underside of the wooden movement surround by two brackets and screws. A rotating brass disc as a dust cover to the winding hole with a large red arrow indicating direction of wind. There is also a label (partly missing) with 'wind slowly' please turn key from left to right. The winding and setting-up squares project through holes in the bottom of the drum. Box 167 mm across the flats, h. 94 mm.

Dial and hands: Engraved, silvered brass dial, the engraving filled with black wax, secured to the front plate by three screws near the edge. In the upper part of the dial is an Up and Down sector with eight divisions for the eight-day going period. On the reverse of the dial repair marks 'Cleaned R E Burreto (?) ap 95' and 'Cleaned Sept 1932'.

Blued steel hands, the minute hand held by a screw in its boss to a square on the cannon pinion. The seconds hand screwed to a pipe having a blind hole. There was once a collet and pin to secure the cannon pinion friction tight on the extended centre arbor.

Movement
Front plate diam. 118·1 mm, reduced to 105·5 mm; back plate diam. 105·4 mm; frame h. 36·5 mm.

Frame: Full plate construction with a high detachable barrel bridge. Four turned pillars, the back plate retained by blued steel screws, two having turned brass washers and two recessed in the back plate. Otherwise similar in construction and execution to cat. no. 34.

Fusee: Reversed and fitted with Harrison's maintaining power and the usual stop-work. The maintaining ratchet wheel brass. On the squared winding arbor is pinned a brass dust-excluding cup. On the inside of the great wheel, under the blued steel maintaining spring, is marked '1804' and 'W^{m} F Rattray

Sept^{r} 12'. The fusee has been turned out on the inside breaking into the chain groove.

Setting-up work for the mainspring is planted on top of the barrel bridge and has a set screw to lock the tail of the click. The barrel arbor is squared on that end only. The mainspring is not tapered, and is hooked by an eye to a hook in the barrel wall and to a hook passing through the brass snailed boss and barrel arbor.

Going-train: With an intermediate wheel and pinion so as to achieve the eight days of running. All the wheels except the fourth and escape are riveted to their pinions, the latter two being mounted on brass collets. The pinions and arbors are polished all over except the undercuts.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the fourth rear and escapement with endstones, that on the balance cock a diamond set in a brass ring. The jewels themselves are set in plain brass discs and not double sunk in their settings in the frame. Where an endstone is fitted the pierced jewel is almost flat on the side remote from the endstone and convex curved towards the endstone. Oil sinks are cut on both sides of these pierced jewels which appear to touch the endstone on their convex sides.

Escapement: Arnold spring detent escapement, the brass wheel soldered to its collet and showing signs of both bending and filing. The cycloidal impulse faces slightly marked by contact with the corner of the impulse jewel but also with file marks. The detent fitted with a steel passing spring held by two rivets, its jewel replaced with a piece of polished steel. The two rollers polished in the usual way. Banking for the detent provided by a brass screw set in the edge of the detent slot.

Balance: 'z' type bimetallic balance with a brass cross bar and central boss fixed to a brass collet on the balance staff by two screws. The blued steel and brass bimetallic rims attached by screws to blocks left integral with the ends of the arms. Steel timing screws are fitted in slotted holes in the blocks to which the rims are screwed, the rims having clearance holes. There is also a tapped hole near the free end of each rim for poising screws, now removed. Brass compensation nuts are on a threaded portion integral with the free ends of the rims. Diam. 31·7 mm over rim, h. 3·8 mm.

Balance spring: An undersprung helical blued steel spring of $5\frac{1}{2}$ turns, with terminal curves, fitted between the balance and the back plate. The collet is a rectangular block of brass with square hole and peg to clamp the spring. The stud, screwed and steady pinned to the back plate, has an adjustable plate with a clamp for the end of the spring, the clamp being arranged to grip the spring concentric with the terminal curve.

Going-train counts:
Great wheel (fusee) 80 teeth (similar to that used in the two-day chronometers, cat. nos 7 and 34)
Intermediate pinion 20 leaves, wheel 80 teeth, 6 arms (wheel similar to great wheel)
Centre pinion 10 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 80 teeth, 4 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 14 leaves (brass)
Hour wheel 42 teeth, minute wheel 56 teeth

Up-and-down work: A lantern pinion of 5 pins on the great wheel arbor meshes with a sector carrying the indicating hand.

Provenance: Ilbert Collection – purchased by Ilbert from Malcolm Gardner in 1930 (reg. no. CAI-1944). Presented by Mr Gilbert Edgar C.B.E. in 1958.

43A JOHN ARNOLD

c. 1825

MARINE CHRONOMETER *Plate 33b–d*

Signature: On the back plate: 'John R. Arnold London Inv^{t} et Fecit No. 595'. On the dial: 'ARNOLD London 595'.

Box: Three-tier brass-bound mahogany box with brass carrying handles. The brass canister supported by gimbals with the usual locking facilities. The tipsy winding key in a gusset in one corner. On the inside of the brass canister is inscribed in faded ink: 'Aug 5 1825.'

The movement is protected by a brass drum fitted with a glazed bezel locked into position with bayonet fittings. The winding hole in the drum bottom furnished with a sprung cover. A key to the lock. Box 160 mm × 158 mm, h. 162 mm.

Dial and hands: Engraved, silvered brass dial, the engraving filled with black wax, secured to the front plate by three pillars. In the upper part 'ARNOLD, London 595', in the lower the subsidiary seconds. On the back scratched 595 and repair marks: 'Mainspring + clean by F. Askew. Sidcup 2, 1886. Feb 3rd, 1.1.14. J.W. Mainspring & Clean JW 9/30 4/07'.

Blued steel hands, the minute hand held by a screw in its boss to a square on the cannon pinion. A collet and pin to secure the cannon pinion friction tight on the extended centre arbor.

Movement
Front plate diam. 71·7 mm; back plate diam. 71·5 mm; frame h. 18·3 mm.

Frame: Full plate construction with a detachable barrel bridge secured by two screws. Four turned pillars, the back plate retained by pins.

Fusee: Of 6 turns, fitted with Harrison's maintaining power, the wheel of brass, and the usual stop-work. On the squared winding arbor is friction fitted a brass dust-excluding cup.

Setting-up work for the mainspring is planted on the top of the barrel bridge and has a blued steel spring to bias the tail of the click. The barrel arbor is squared on that end only and is drilled for a pin to secure the ratchet wheel. The mainspring has a solid hook. The steel barrel arbor has a snailed boss.

Going train: All the wheels except the escape are riveted to their pinions, the later being mounted on a brass collet. The pinions and arbors are polished all over except the undercuts.

Jewelling: The upper pivots of the third and fourth wheels and the escapement arbors in pierced jewels, those of the escapement with endstones, that in the balance cock a diamond set in a brass ring. The jewels themselves in brass settings which are double sunk in the frame.

Escapement: Arnold spring detent escapement, the wheel of brass. The cycloidal impulse faces marked by contact with the corner of the impulse jewel. The detent fitted with a gold passing spring held by a rivet, its jewel replaced with a piece of steel. The two rollers jewelled in the usual way. Banking for the detent provided by an eccentric brass disc screwed to the edge of the detent slot.

Balance: 'U and O' balance.[1] The 'U' part of the balance on Hardy's plan with screwed weights, the 'O' part for poising being circular with three small movable weights. Timing nuts at the ends of the crossarm for bringing the chronometer to time. Diam. 35·0 mm, h. 16 mm.

Balance spring: An undersprung gold helical spring of $7\frac{3}{4}$ turns, with terminal curves, fitted between the balance and the back plate. The collet is a rectangular block of brass with square hole and peg to clamp the spring. The stud, screwed and steady pinned to the back plate, has an adjustable plate with a clamp for the end of the spring, the clamp being arranged to grip the spring concentric with the terminal curve.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 14 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400 (see cat. no. 42 for similar train)

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves (brass)
Hour wheel 60 teeth, minute wheel 64 teeth (see cat. no. 53 for similar motion work).

Provenance: Purchased in 1978 (reg. no. 1978, 12–3, 1).

Note

1. The 'U and O' balance is a development of the 'U' balance patented by J. R. Arnold in 1821 (Patent No. 4531). The date in ink in the canister perhaps records the date of sale, certainly it agrees with the estimated date of this chronometer.

44 JOHN ROGER ARNOLD

c. 1805 (No. 1922 has the hallmark for 1805 and No. 1984 for 1806)

CHRONOMETER MOVEMENT *Plate 33e–f*

Signature: 'Jo° R. Arnold London Inv^{t} et Fecit No 1975.'

Dial and hands: Badly damaged enamel dial, remains of the signature in capitals only (see cat. no. 41).
Hands missing.

Movement
For similar movements see cat. nos 40 and 41.

Dial plate diam. 45·1 mm; front plate diam. 42·1 mm; back plate diam. 41·6 mm; frame h. 8·1 mm.

Frame: Similar to cat. no. 40, but the dial plate foot near the case catch retained by a blued steel screw. The case hinge torn out.

Fusee: Similar to cat. no. 40. The setting-up ratchet wheel on the barrel bridge is not original, the foot of the return spring for the click has been shortened.

The maintaining detent spring instead of being part of a screw pointing down from the back plate is a normal blued steel spring screwed to the front plate on the movement side.

Going train: Similar to cat. no. 40.

Jewelling: Similar to cat. no. 40 except for a ruby endstone on the balance cock instead of a diamond, and the impulse roller not jewelled.

Escapement: Similar to cat. no. 40. The impulse roller is unusual in that it is not jewelled and has a small hole drilled opposite the impulse face for poising. The impulse corner is rounded. The escape wheel teeth practically unmarked on the impulse faces.

Balance: Similar to cat. no. 40 but the blocks on the ends of the crossbar finished differently. Diam. 18·3 mm, h. 2·6 mm.

Balance spring: Possibly a later blued steel helical spring because the securing pins to collet and stud are round instead of square in section, and a new round hole has been drilled in the stud above the original square hole. The spring has 7 complete turns, with terminal curves.

Balance cock: Engraved decoration similar to cat. nos 40, 41 and 47.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, hour wheel 42 teeth

Minute wheel and pinion missing but no doubt 48 teeth and 14 leaves respectively.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1934 (reg. no. CAI-1582).

45 JOHN ROGER ARNOLD

c. 1806. This watch fits into the same series as cat. nos 40, 41, 44, 46 and 47.

CHRONOMETER *Plate 34a–b*

Signature: 'Jn° R Arnold London Inv^{t} et Fecit No. 1962'.

Case: Later silver case, maker's mark J.D., London hallmark for 1816. Diam. 53 mm, overall h. 21·8 mm.

Dial and hands: Later dial and hands, the enamel dial with the inscription 'Chronometer' and the number 1962 in the upper half.

Movement
Dial plate diam. 47·0 mm; front plate diam. 42·3 mm; back plate diam. 41·3 mm; frame h. 8·0 mm.

Frame: Similar to cat. nos 40, 41, 44 and 47. The detent slot has a piece let in and soldered at the foot end and has been further filed to admit a replacement detent.

Fusee: Similar to cat. nos 44 and 46. The setting-up ratchet wheel retained on the squared portion of the barrel arbor by a pin.

Going train: Similar to cat. nos 40, 41 and 44 but with an unusual number of beats per hour caused by the escape wheel of sixteen teeth.

Jewelling: The pivots of the fourth wheel in pierced jewels and those of the escapement in pierced jewels with endstones. A clear sapphire endstone in a blued steel ring on the balance cock.

Escapement: Arnold spring detent escapement probably a good deal altered in detail. The escape wheel has three arms isntead of the usual four and sixteen teeth instead of fifteen; the impulse faces have been filed at some time but still show signs of wear. The jewelled discharge roller is as usual but the badly rusted detent is certainly a replacement. The impulse roller also a replacement as the impulse face is leaning towards a radius from the centre to the rounded impulse corner, instead of being on this radius. The impulse face is not jewelled, but both it and the edge, top and bottom of the roller are polished.

Balance: Two-armed brass and steel bimetallic balance of Earnshaw type, the steel parts blued. Segment-shaped brass compensation weights held in by screws from the inside. Timing screws set in the rims at the ends of the arms. Diam. of rim 18·3 mm, h. 1·71 mm.

Balance spring: Blued steel spiral spring with an overcoil and terminal curve, pinned to a blued steel stud on the balance cock.

Balance cock: The upper surfaces engraved with an acanthus leaf and flower motif and with a cornucopia of flowers.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 16 teeth, 4 arms
Beats per hour: 19,200

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Belk in 1932 (reg. no. CAI-1840).

46 JOHN ROGER ARNOLD
1806

CHRONOMETER *Plate 34c–f*

Signature: 'Jn^{o} R Arnold London Inv^{t} et Fecit no 1984' on the back plate. On the dial 'Arnold 1984'.

Case: Silver consular case with the maker's mark T.H., numbered inside the dome 1984, London hallmark for 1806. On the back a coat of arms with the motto 'Regard Bien'.[2] Diam. 58·2 mm, overall h. 24·6 mm.

Dial and hands: Perfect enamel dial with cursive signature and number. The dial plate carrying the movement hinge at 12 o'clock, the dial fixed to it by short feet and pins. The dial plate fixed to the front plate by short feet and pins.

Blued steel hands, the seconds screwed to its steel pipe.

Movement
Dial plate diam. 49·2 mm; front plate diam. 44·8 mm; back plate diam. 44·1 mm; frame h. 8·4 mm.

Frame: Similar to cat. no. 46. The case catch and spring screwed to the front plate under the dial. On the inside of the dial plate is scratched 'Arnold 1984'.

Fusee: Similar to cat. no. 46 except that the setting-up ratchet is pinned to the squared barrel arbor, and its click spring foot planted midway between the outer and inner edges of the barrel bridge.

The mainspring is marked 'June 1854 J.B.'

Going train: Similar to cat. no. 46.

Jewelling: Similar to cat. no 40.

Escapement: Similar to cat. nos 40 and 46, the impulse faces of the brass escape wheel teeth marked, the steel passing spring on the detent secured by a single rivet.

Balance: Similar to cat. nos 40, 41, 44 and 46 except that the blocks to which the bimetallic rims are fixed are of a slightly different shape. The compensating screws of gold. Diam. 28·8 mm, h. 2·62 mm.

Balance cock: The engraved decoration on the top surfaces having an acanthus leaf and basket of flowers motif (see cat. nos 40, 41, 44, 45, 47 and 52).

Balance spring: Gold helical spring of 7 complete turns and with a terminal curve at each end. Square-section pins in the collet and overhanging adjustable stud as for cat. nos 47, 48, 59, 50 and 51.

Going-train counts:
Great wheel 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; Ilbert purchased this chronometer from Benson in 1935 (reg. no. CAI-1842).

Notes

1. This is a particularly fine specimen, in almost mint condition, of the series of chronometers cat. nos 40, 41, 44 and 46.
2. The coat of arms is that of Milliken (of that Ilk, co. Renfrew, Scotland).

47 JOHN ROGER ARNOLD

c. 1806 (no. 2029 has the hallmark for 1807)

CHRONOMETER MOVEMENT *Plate 35a–b*

Signature: 'Jn^{o} R. Arnold London Inv^{t} et Fecit no 2014'.

Dial and hands: Perfect enamel dial with cursive signature and number. Fixed as cat. no. 40.

Gold hands, the seconds hand screwed to its pipe.

Movement

Dial plate diam. 49·0 mm; front plate diam. 45·0 mm; back plate diam. 44·0 mm; frame h. 8·3 mm.

Frame: Similar but slightly larger than cat. no. 40 except that the foot of the dust guard round the fusee winding square is a different shape.

Fusee: Similar to cat. no. 44 except that the foot of the setting-up click spring is placed nearer the inner edge of the barrel bridge, and the click itself has a limiting pin set in the barrel bridge.

Going train: Similar to cat. no. 40 but the centre wheel and third pinion counts different.

Jewelling: Similar to cat. no. 40 except that the endstone plate on the balance cock for the diamond endstone is not blued.

Escapement: Similar to cat. no. 40, the impulse faces of the escape wheel teeth marked. The steel passing spring attached to the detent by a single rivet.

Balance: Similar to cat. no 44. Diam. 20·3 mm, h. 2·6 mm.

Balance spring: Blued steel helical spring of 5 complete turns, with a terminal curve at each end. Pinned with square-section steel pins to stud and collet. The stud is not mounted on the balance cock, but is screwed to the back plate at the end of the barrel bridge. It is adjustable by the two round-headed screws where it overhangs the balance, and is made of gilded brass.

Balance cock: Similar decoration to cat. nos 40, 41, 44.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Jauncey in 1935 (reg. no. CAI-1583).

48 JOHN ROGER ARNOLD

Probably 1811 (nos 3099 and 3605 are dated 1811)

CHRONOMETER *Plate 35c–d*

Signature: On the barrel bridge 'Jn^{o} R. Arnold London'. On the back plate 'No. 3580'.

Case: Not original. Silver engine-turned open face of French origin with the French quality control mark for 1819. Inside the dome the number 4128B and inside the back 1948 with the B beneath. Diam. 53·0 mm, overall h. 19·7 mm.

Dial and hands: Flat enamel dial with subsidiary seconds at 6 o'clock. The signature 'Arnold' in cursive script in the upper half.

Gold minute and hour hands, the minute not original, blued steel seconds hand also not original.

Movement

A new series from the preceding, and of poorer quality. Ebauche marks on the front plate under the dial 18, 9.

Dial plate diam. 54·8 mm; front plate diam. 43·2 mm; back plate diam. 40·7 mm; frame h. 7·3 mm.

Frame: Full plate with detachable barrel bridge, four turned pillars, the back plate retained by pins. The movement hinge riveted to the dial plate at 12 o'clock, the case catch opposite and attached with its spring to the dial side of the front plate. The original dust-excluding ring around the edge of the frame (now missing) was held by two eccentric-headed blued steel screws. No dust pipe round the winding square.

Fusee Keywind fusee fitted with stop-work and maintaining power, brass maintaining ratchet wheel, the detent for this missing. The setting-up-work under the dial on the front plate.

Going train: Similar train to cat. nos 40, 41 and 44 except that the escape wheel has sixteen teeth.

Jewelling: The fourth pivot on the dial side only in a pierced jewel. The pivots of the escapement in pierced jewels, with endstones, that in the balance cock a plain ruby endstone set in a blued steel ring. The discharge roller jewelled, the impulse roller plain steel.

Escapement: The remains of an Arnold detent escapement, the sixteen-teeth brass escape badly damaged, the detent broken and only the foot remaining.

Balance: Bimetallic balance of Earnshaw type with wide crossbar and brass segment weights secured by polished steel screws. Two small gold screws set in the rims near their fixed ends. The outer edges of the rims graduated with a series of vertical scratches. Diam. of rim 17·3 mm, h. 1·5 mm.

Balance spring: Blued steel flat spiral spring without terminal curve pinned to an overhanging blued steel stud screwed to the back plate by the winding square. A blued steel index fitted under the balance cock and with its tail passing over a graduated sector on the back plate.

Balance cock: Plain (i.e. no engraving or other decoration). The cock screw not original and the hole in the cock through which it passes mutilated.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 16 teeth, 4 arms
Beats per hour: 19,200

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Davidson in 1932 (reg. no. CAI-1844).

49 JOHN ROGER ARNOLD

1818

CHRONOMETER *Plate 35e–f*

Signature: 'Jn^{o} R. Arnold London Inv^{t} et Fecit No. 2161'. The 'London' engraved in Gothic lettering and the number positioned on the barrel bridge.

Case: Silver case with heavy pendant, the front glazed bezel, and back, snapping on to the middle. London hallmark for 1818, the maker's mark T.H. Diam. 55·5 mm, overall h. 24·7 mm.

Dial and hands: The flat enamel dial has the signature in gothic letters. The seconds hand a later addition. The minute and hour hands of blued steel, the minute hand having a round hole in its boss and adjusted flush on the end of the cannon pinion. The hands can only be set by pushing the minute hand itself. This is unlike any of the previous examples in which the cannon pinion has an extended square onto which the minute hand is adjusted, leaving room to apply the key for setting to time.

Movement
Dial plate diameter 49·0 mm; front plate diam. 45·0 mm; back plate diam. 44·4 mm; frame h. 8·6 mm.

Frame: Full plate with detachable barrel bridge with four turned pillars, the back plate retained by pins. The movement hinge screwed to the dial plate at 12 o'clock, the catch opposite attached to the front plate with its return spring. The dial plate apparently mercurial gilded and secured to the front plate by three short feet and pins. The gilding very pale, possibly electro-gilded over the original. Note also the rounded foot of the dust pipe round the winding square. The foot of the balance potance has an unusual moulding along the edge nearest the edge of the back plate; the potance has been moved. The dial with two feet and pins to secure it to the dial plate. The frame screws on the front plate under the dial all polished flat. The maintaining detent and case catch springs left with a rough-grained finish.

Fusee: Keywind fusee fitted with stop-work and maintaining power, brass maintaining ratchet wheel. The blued steel maintaining detent pivoted between the plates, with its grained steel spring screwed to the inside of the front plate. The setting-up ratchet wheel squared to the extended barrel arbor on the barrel bridge. The wheel, its click and the return spring polished.

Going train: Train similar to cat. nos 46 and 47, but the escape wheel of 16 teeth gives the unusual number of 19,200 beats per hour.

Jewelling: The fourth arbor lower pivot and those of the escapement in pierced jewels, the escapement with endstones. A diamond endstone set in a blued steel plate on the balance cock. Top escape jewel setting not original.

Escapement: Arnold spring detent escapement with brass escape wheel of sixteen teeth mounted on a polished steel collet on the escape pinion arbor. The acting surfaces of the escape wheel slightly cut. Normal jewelled discharge roller. The impulse roller jewelled radially (see cat. no. 40). The grey steel detent with square foot, and bevelled sides as in Swiss work. The banking for the detent by a round steel plate held by an eccentric screw to the back plate (see cat. no. 50). All the pivots of the escapement of modern Swiss form. Gold passing spring riveted to detent.

Balance: 'z' type with separate bimetallic rims screwed to upstanding blocks on the ends of the crossbar. Timing nuts on studs set in the blocks on the ends of the crossbar. Poising screws, one missing, the other very small, set radially in holes near the free ends of the rims. Diam. 19·5 mm, h. 2·6 mm.

Balance spring: Later flat spiral blued steel spring with terminal curve pinned to an overhanging adjustable stud screwed to the back plate at the end of the barrel bridge. This probably replaces an original helical spring.

Balance cock: Plain and without decoration, and with a small hole drilled on the centre line about halfway along the overhanging portion. A new adjustable sliding stud fitted to the existing foot.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 16 teeth, 4 arms
Beats per hour: 19,200

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Willis Room, The Old Wells Collection (reg. no. CAI-1843).

Note: Most of the steel parts show signs of refinishing, suggesting that the watch has at some time been in water and the steel parts rusted as a result. The edges of many of these parts still show extensive signs of rusting. This would also explain the replacement detent, the spiral steel balance spring, and the electro-gilding. The unusual slope of the balance potance foot moulding remains a mystery.

50 JOHN ROGER ARNOLD

c. 1820 (No. 2173 has the hallmark for 1819)

CHRONOMETER MOVEMENT *Plate 36a–b*

Signature: 'Jn° R. Arnold London Invt. et Fecit No. 2175'.

Dial and hands: The dial missing, but the dial plate still in place fixed to the front plate by three steel screws. The balance was originally visible through a glazed aperture in the dial, the rim and glass still extant.

Blued steel offset minute and hour hands, and sweep centre seconds hand. The sweep seconds hand with steel pipe and polished circular counterpoise end.

Movement

Dial plate diam. 51·0 mm; front plate diam. 43·8 mm; back plate diam. 43·1 mm; frame h. 7·8 mm.

Frame: Unusual full plate construction, three turned pillars supporting the back plate retained by pins. The detent and a cock for the balance lower bearing mounted on the back plate. The balance itself mounted under the dial and supported by a somewhat flexible cock screwed to the dial side of the front plate. The back plate also cut away to clear the going barrel, pivoted and standing off the front plate. A separate cock under the dial for the third and fourth wheel pivots on that side. A hole through the dial plate, with masking bridge to prevent ingress of dust, for ease of timing screw adjustment.

Going barrel: Mounted on the front plate with its ratchet wheel under a bridge on the dial side.[1] The barrel arbor squared on both ends, one end for winding and the other on the front plate and passing into a squared hole in the ratchet wheel. The ratchet wheel itself having a short pipe providing a pivot in the barrel bridge. The squared barrel arbor and the ratchet wheel pipe are pinned tightly together. A four-turn Geneva stop-work fitted on the barrel cover. Dust pipe with its foot fixed to the barrel cover.

Going train: So arranged that the fourth wheel is at the centre and can carry the sweep centre seconds hand. The centre wheel is offset but carries the canon pinion and drives the motion work in the ordinary way. An unusually fast train of 21,600 causing the seconds hand to advance three times per second.

Jewelling: The fourth pivot on the dial side running in a jewelled hole. The pivots of the escapement running in jewelled holes with endstones. Both balance endstones are diamond, the one at the dial side loose, not in a setting. The detent, impulse and discharge rollers jewelled at their working surfaces.

Escapement: Arnold spring detent escapement, the brass escape wheel having the usual number of eighteen teeth. The impulse surfaces of the escape wheel teeth only slightly marked, suggesting that the watch has had little use. An eccentric plate and screw are banking for the detent.

Balance: Earnshaw-type balance, the steel part of the rims and the crossbar are part of the same piece of steel. Adjustable brass segment compensation weights held by round-headed steel screws. Additional adjustable weights made of screws fixed to the crossbar. Timing screws set radially at an angle in the shorter sections of the bimetallic rim, which are bent inwards. Diam. 17·0 mm, h. 1·23 mm.

Balance spring: Duo-in-uno blued steel spring pinned to the adjustable steel overhanging stud with a square section pin, and to the steel collet with a D-shaped pin.

Going-train counts:
Great wheel (barrel) 64 teeth
Offset centre pinion 8 leaves, and wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 18 teeth, 4 arms
Beats per hour: 21,600

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Jauncey in 1936 (reg. no. CAI-1584).

Note

1. J. R. Arnold began to use the going barrel in his marine chronometers in 1807.

51 JOHN ROGER ARNOLD

c. 1820

CHRONOMETER *Plate 36c–d*

Signature: 'On the exceptionally large barrel bridge 'John R. Arnold London No 3772'.

Case: Later silver open face, maker's mark P.W. and with London hallmark for 1886. Pendant has mark PW with London hallmark for 1885. The movement retained by two large dog screws with polished rounded heads on the back plate, these screws added later. Diam. 53·5 mm, overall h. 19·7 mm.

Dial and hands: Flat enamel dial without subsidiary seconds, signed *Arnold London* in Gothic script across the middle. The back of the enamel dial signed 'Sanders, Arnold London 3772' and '12, Hour'(?) Probably in the same series as cat. no. 48.

Blued steel minute and hour hands, the minute hand not original.

Movement

Ebauche marks 220 on the front plate under the dial.

Dial plate diameter 46·4 mm; front plate diam. 43·7 mm; back plate diam. 40·7 mm; frame h. 7·3 mm.

Frame: Full plate with very large detachable barrel bridge, four turned pillars, the back plate retained by pins. Neither hinge nor case catch apparently ever fitted. No dust pipe around the winding square. Dial plate scratched '3 hole Arnold Sanders'.

Fusee: Keywind fusee fitted with stop-work and maintaining power, brass maintaining ratchet wheel, the maintaining detent and return spring of blued steel. The setting-up-work on the front plate under the dial.

Going train: A different count is used to any of the other examples by either Arnold. The layout of the train is quite normal.

Jewelling: The fourth pivot on the dial side only in a pierced jewel. The pivots of the escapement in pierced jewels with endstones, that in the balance cock a plain ruby endstone set in a blued steel ring. The impulse and discharge rollers and the detent jewelled on their acting surfaces.

Escapement: Arnold spring detent escapement, with brass escape wheel with sixteen teeth, their acting surfaces marked. The grey steel detent set with its foot on the edge of the back plate. Detent banking by means of a gold disc screwed eccentrically. The D-shaped locking stone made from a round piece of ruby instead of the usual flat slip, now broken. The passing spring gold, attached by a single rivet.

Balance: Bimetallic balance of Earnshaw type with very narrow crossbar, and brass segment weights clamped by polished rounded steel screws. No graduations on the outer edges of the rims. Timing and poising screws set in the rims at the ends of the crossbar. Diam. of rim 16·5 mm, h. 1·90 mm.

Balance spring: Blued steel flat spiral spring without terminal curve pinned to an overhanging polished steel stud with square hole screwed to the barrel bridge near to the winding square, brass rectangular collet with round hole. A blued steel index fitted under the balance cock and with its tail passing over a graduated sector on the barrel bridge.

Balance cock: Asymmetrical and without decoration.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 16 teeth, 4 arms
Beats per hour: 19,200

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Ash in 1932 (reg. no. CAI-1845).

II.iv (cat. nos 52–56)

THE ARNOLD SPRING DETENT ESCAPEMENT AS USED BY OTHER MAKERS

In 1806, the Commissioners of the Board of Longitude published *Explanations of Time-Keepers constructed by Mr Thomas Earnshaw and the late Mr John Arnold*, thus making available to others the details and many of the secrets of construction adopted by these two pioneers in the field. This was done deliberately to foster and advance the art and science of chronometer-making. Further encouragement was given in the form of rewards of one kind or another, following trials of chronometers at the Royal Observatory, Greenwich. Most makers used the helical balance spring with terminal curves patented by John Arnold in conjunction with a form of Earnshaw escapement and bimetallic balance. Some makers, however, based their chronometers closely on Arnold's plan, examples in this section are those signed 'Tho^s Percival' (cat. no. 53), and 'Perigal and Brown' (cat. no. 55). It is not surprising that Urban Jürgensen, who studied with John Arnold before returning to his native Denmark, should use Arnold's escapement, but his version is highly individual (cat. no. 56).

The five chronometers in this section range in date from 1800 to 1820. They all have fusees.

52 J. GRANT

c. 1800

CHRONOMETER MOVEMENT *Plate 36–f, 37a–b*

Signature: On the back plate 'GRANT Fleet Street London 2444'. On the enamel dial 'GRANT Fleet Street LONDON No 2444'.

Dial and hands: Flat enamel dial with intersecting offset minute and hour, and seconds circles, secured by four short feet and pins to the dial plate. Signed in red on the reverse W and W or, more probably, M and M.

Gold hands of the solid moon type.

Movement
Dial plate diameter 48·1 mm; front plate diam. 44·6 mm; back plate diam. 41·6 mm; frame h. 7·5 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, detachable barrel bridge engraved with scrolling foliage. The dial plate carrying the hinge and fixed to the front plate by four short feet and pins, GRANT scratched on this plate. The case catch and spring mounted on the front plate under the dial. The balance cock engraved with scrolling foliage and a mask.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel brass. Setting-up-work under the dial on the front plate, the barrel arbor squared at that end only. The barrel with a flange at the cover end.

Going train: The brass wheels gilded, the steel pinions and arbors well finished and polished. The train count chosen to give the unusual number of 16,875 beats per hour.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones, a diamond on the balance cock, set in a blued steel ring.

Escapement: An Arnold type of detent escapement, with brass escape wheel, the impulse faces of the teeth marked. The steel impulse roller set with a jewel leaning towards a radial to its slightly rounded acting tip as for an Earnshaw type of escapement. The discharge roller jewelled, and with two flats for adjusting. The detent of very similar design to that used by the Arnolds, the steel passing spring held by a single rivet. The detent banking provided by a steel strip and single screw, lodged in a slot in the top of the back plate.

Balance: Bimetallic two-armed balance with cylindrical brass compensation weights held by polished steel screws. Steel timing screws set in the rim near the ends of the arms. Diam. of rim 20·0 mm, h. 1·47 mm.

Balance spring: Blued steel helical spring, 4½ turns and with terminal curves, free sprung to a blued steel stud on he balance cock. The steel collet having a short thick piece of gold wire set in a hole opposite the pinning point of the spring, to act as a counterpoise.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 6 arms
Fourth pinion 8 leaves, wheel 75 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 16,875

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Biggs of Maidenhead (reg. no. CAI-1802).

53 THOMAS PERCIVAL
1802–8

CHRONOMETER MOVEMENT *Plate 37c–f*

Signature: On the back plate 'Thos. Percival London No 815'; repeated on the dial.

Dial and hands: Flat enamel dial signed THO^S PERCIVAL LONDON 815, probably later, attached to the dial plate by three feet and pins.

Brass minute and hour hands, not original. Blued steel seconds hand.

Movement
Dial plate diameter 47·5 mm; front plate diam. 45·2 mm; back plate diam. 42·8 mm; frame h. 8·7 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins. The escape wheel arbor lower bearing carried in a cock on the dial side of the front plate. A small plate screwed to the front plate on the inside under the barrel, to act as a chain guard. The dial plate with the movement hinge attached by screws, fixed to the front plate by four feet and pins. Repair marks on the dial plate: 'W. Hislop 1880 Ea Matthews 1918 Collin 1811' or possibly 1818. The case catch and spring on the front plate under the dial. The dust cover pierced for the balance cock table and overhanging part of the stud, held by a polished steel clip to two studs on the back plate. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass. The setting-up-work on the front plate under the dial, the barrel arbor with an extended square on that end only.

Going train: Well made and finished but unusual in the train count and the third and fourth wheels having six arms for what is apparently so early a watch.

Jewelling: The pivots of the fusee, the lower centre, third, fourth and escapement arbors in jewelled holes, those of the escapement with endstones. The pierced jewels have adequate oil sinks, the endstone jewels are flat, except the diamond set in a polished steel ring on the balance cock.

Escapement: Arnold spring detent escapement with solid, blue-white, sapphire impulse roller. The steel discharge roller integral with the steel boss for the balance has the unlocking jewel crossing the centre and dovetailed in place. The detent jewelled with a piece of jewel having the locking side straight, the back sloping and the slot dovetailed to take the jewel. A steel passing spring held by two rivets. The escape wheel of steel with all surfaces polished except the sunk portions of the rim and arms. Some marking has occurred on the impulse surfaces of the teeth where they contact the corner of the impulse face of the roller. The escapement as set has only a moderate amount of drop-on.

Balance: Similar to John Arnold's 'OZ' balance, built up on a three-armed gilded brass wheel with attached bimetallic rims. The compensation nuts brass, the quarter screws steel. The wheel itself held with two screws on a steel boss on the balance staff. Diam. 22·0 mm, h. 2·0 mm.

Balance spring: Blued steel helical spring of 4¼ turns, with terminal curves, free sprung to an adjustable stud overhanging the balance and screwed to the back plate. The brass collet drilled with a poising hole on the same side as the pinning and with an extended boss at the balance staff.

Going-train counts:
Great wheel (fusee) 54 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 6 arms
Fourth pinion 8 leaves, wheel 65 teeth, 6 arms
Escape pinion 7 leaves, wheel 16 teeth, 4 arms
Beats per hour: 17,828$\frac{4}{7}$

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves
Hour wheel 60 teeth, minute wheel 64 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Benson in 1935 (reg. no. CAI-1744).

Note: The layout and construction show a strong resemblance to the series of small chronometers made by the Arnolds, father and son.

54 C. HALEY
c. 1800

CHRONOMETER *Plate 38a–d*

Signature: On the back plate and barrel bridge 'Haley Wigmore Street, London MNN'. On the dial HALEY LONDON and 6 over MNH.

Case: Case not original. The movement a loose fit in the case badly burred around winding hole, poorly cut out clearance for catch, movement hinge filed to clear case. Silver consular case with London hallmark for 1812 and the maker's mark WB over GH on the inside of both dome and back. Diam. 56·9 mm, h. over the glass 24·0 mm.

Dial and hands: Flat enamel dial with many hair cracks and attached to the dial plate by three feet and pins.

Blued steel spade hands, the second hand fitted onto a gold tube with a cap over the boss of the hand.

Movement
Dial plate diam. 50·4 mm; front plate diam. 49·0 mm; back plate diam. 43·0 mm; frame h. 8·8 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, detachable barrel bridge. The dial plate carrying the movement hinge attached to the front plate by three short feet and pins. The case catch and spring mounted on the front plate under the dial. The front plate cracked from the edge towards the maintaining detent hole. All the brass parts gilded.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work under the dial on the front plate, the barrel arbor squared on that end only.

Going train: The usual arrangement, the brass wheels gilded, the steel pinions and arbors polished.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, the escapement with endstones. A ruby endstone on the balance cock set in a polished steel ring.

Escapement: Arnold type of detent escapement with brass escape wheel, the impulse surfaces of the teeth unmarked. The steel impulse roller with a jewelled impulse surface made in a similar way to Arnold's but with a radius on the corner on which impulse is received. The steel discharge roller with a jewel, and flat for adjusting.

Balance: Similar to the Arnold 'z' type. Steel crossbar with blocks left standing on the ends. Brass and steel bimetallic rim pieces screwed to the upstanding blocks with two screws each. Steel timing screws passing through clearance holes in the rims into slotted holes in the blocks. Steel quarter screws set in the rims near their free ends. Brass compensation weights on curved threaded rods on the free ends of the rims. The balance mounted on a brass collet on the balance staff.

Balance spring: Blued steel helical spring of $5\frac{1}{4}$ turns, with terminal curves. Polished steel stud on the balance cock with round hole and pin to clamp the end of the upper terminal curve. Brass collet with similar clamping for the lower terminal curve. Diam. of rim 19·6 mm, h. 2·47 mm.

Balance cock: The upper surfaces decorated with flower and acanthus leaf motifs.

Going-train counts:
Great wheel (fusee) 62 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Hutchinson, 1935 (reg. no. CAI-1736).

55 PERIGAL AND BROWN
1818

CHRONOMETER *Plate 38e–f, 39a*

Signature: On the back plate 'Perigal and Brown Coventry Street London No 3020'.

Case: 18-carat gold pair cases with the London hallmark for 1818 and the marker's mark: a sunburst with central face in a cartouche similar to that for the hallmark. Outer case diam. 61·5 mm; inner case diam. 56·1 mm, h. over glass 26·1 mm.

Dial and hands: Flat enamel dial; the minute and second markings appear to be engine divided with a scriber on turned rings before the application of the black enamel. The dial secured to the dial plate by three short feet and pins.

Flat, red-gold hands.

Movement
Dial plate diam. 53·0 mm; front plate diam. 50·6 mm; back plate diam. 50·3 mm; frame h. 8·0 mm; front plate th. 1·45 mm; back plate th. 1·10 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins. The dial plate carrying the movement hinge secured to the front plate by four short feet and pins. The case catch and spring on the front plate under the dial. No dust cover or any provision for one. All the brass parts nicely gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, with brass maintaining ratchet wheel. Blued steel setting-up-work on the front plate under the dial, the barrel arbor with an extended square on that end only. The barrel with a very small narrow flange on the cover end.

Going train: The upper end of the centre pinion polished integral with the arbor. The brass wheels gilded, the pinions and arbors well finished and polished.

Jewelling: All the pivots of the going train arbors, including the fusee, in fine large pierced jewels with screwed settings. The escapement pivots in pierced jewels with endstones. A large diamond in a blued steel setting on the balance cock.

Escapement: Arnold spring detent escapement. The escape wheel of a pale coppery colour, with arms and rim sunk below the level of the teeth. The leading edges of the teeth almost straight, not cycloidal, and marked. A solid blue-white sapphire impulse roller with a deep notch. The impulse face a radial and with a slightly rounded corner. The jewelled steel discharge roller with a flat for adjusting. The well-made detent with polished top to the foot, gold passing spring held by a single rivet, and the locking stone made from a flat piece of jewel set in a slot in the detent. Banking provided against a screw in a slot in the backplate in a similar way to that usually used by the Arnolds.

Balance: Bimetallic two-armed balance, the rims integral with the arms. Steel pieces screwed to the free ends carrying brass compensation nuts on threaded rods. Steel timing screws at the ends of the arms. Small gold screws set in the rim near their fixed ends. An unfilled hole in one balance arm midway from the centre. The balance riveted to a brass collet on the staff.

Balance spring: Blued steel helical spring of 4½ turns, with terminal curves, free sprung to an overhanging adjustable stud screwed to the back plate. A brass bar-shaped collet. Diam. 22·0 mm, h. 1·92 mm.

Balance cock: Pierced and engraved decoration unusual in a watch of this date. A small brass peg points downwards from a hole in the edge of the table on the side nearest the winding square.

Going-train counts:
Great wheel (fusee) 62 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Webster in 1931 (reg. no. CAI-1737).

56 URBAN JÜRGENSEN (1776–1830), Danish
c. 1820

CHRONOMETER MOVEMENT *Plates 39b–e, 40a*

Signature: On the back plate and on the dial URBAN JÜRGENSEN

Dial and hands: Flat enamel dial with small sunk subsidiary seconds dial. Canister dial with a positioning peg.
Blued steel minute and hour hands, seconds hand missing.

Movement
Ebauche marks UI under a crown and 424.
Front plate diam. 49·1 mm; back plate diam. 47·4 mm; frame h. 8·7 mm.

Frame: A type of three-quarter plate construction built up on a massive front plate, and without a dial plate. Four conical turned pillars, the back plate retained by marked blued steel screws. Detachable crescent-shaped barrel bridge. The movement retained in its case by two polished steel dog screws in the front plate, and a positioning peg. The various bridges and cocks without screwdriver slots to aid their removal during dismantling. All the brass parts nicely gilded.

Fusee: Fitted with Harrison maintaining power, steel ratchet wheel and pivoted maintaining detent, with its return spring on the inside of the front plate, the tail under the balance. A modified six-turn Geneva stop-work fitted on the front plate under the dial with the setting-up-work. The barrel arbor with an extended square on the front plate end only.

Going train: The centre wheel snailed on both sides not gilded, all the other wheels gilded. The steel arbors well polished and finished. An unusual train count is used with a fourth wheel of 54 teeth giving 16,200 beats per hour of the balance.

Jewelling: The third, fourth and escape wheel arbor pivots in pierced jewels with flat faces against the pivot shoulders. The balance pivots in pierced jewels with endstones, a diamond endstone in the balance cock, set in a blued steel ring.

Escapement: Spring detent escapement of basically Arnold design. The brass escape wheel with cycloidal impulse faces to the teeth. Steel detent and passing spring, the foot of the detent screwed and steady pinned to a gilded brass arm passing round the fourth wheel sink on the edge of the front plate. An adjusting screw in the end of the brass arm acting on a steel pillar can be used to move the detent towards or away from the balance centre. The detent banked against a brass screw with steel clamping screw set in a brass piece screwed and pinned to the front plate. The locking stone of rectangular section with one short side rounded, and set in a hole in the detent of exactly matching shape. The steel impulse roller with radial face to the pallet and sharp corner to receive impulse. Large oval counterpoising hole opposite the impulse pallet. The usual jewelled discharge roller between the impulse roller and the balance. The escapement is set up so that the escape wheel teeth have a heavy drop on at the beginning of impulse, which has resulted in the impulse faces of the teeth being cut where they have met the corner of the impulse pallet. (C.f. other watches with this type of detent escapement, especially those by the Arnolds, father and son.)

Balance: Bimetallic two-armed balance with brass segment weights held by steel screws from underneath, and with steel timing screws at the ends of the arms. The steel parts of the balance do not appear to have been hardened and tempered. Diam. 19·5 mm, h. 2·3 mm.

Balance spring: Blued steel helical spring of 6½ turns, with terminal curves. Poised steel collet on the balance staff, adjustable overhanging stud fixed to the back plate as used by John Arnold.

Amplitude limiting device: The basic design similar to that used by the Brockbanks. A pivoted arm is acted on by the balance spring and caused to move into the path of a stud on one balance arm, when the amplitude increases beyond a certain value and before the escapement unlocks twice with the balance turning in the same direction. With the balance spring as fitted the device cannot work, the diameter of the spring being too small. This suggests that the balance spring is a later replacement of smaller diameter than the original.

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 14 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 54 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 16,200

Motion work:
Cannon pinion 12 leaves, minute pinion 18 leaves, mounted on a tube on the minute wheel
Hour wheel 48 teeth, minute wheel 54 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Gardner in 1932 (reg. no. CAI-1605).

II.v (cat. nos 57–70)

THOMAS EARNSHAW'S SPRING DETENT ESCAPEMENT

Earnshaw first used a pivoted detent escapement in his chronometers although none of these watches have survived. The patent for his form of spring detent escapement, No. 1354, was taken out on his behalf by Thomas Wright in 1783 after a good deal of delay (see figs 4 and 4a).

The first watch in this series of fourteen that can be credited to Earnshaw, regardless of how they are signed, bears the ébauche mark T.W. In the notes on this watch, cat. no. 57, the way in which Wright was recompensed for his costs in taking out the patent is explained. Also mentioned is the fact that other makers' names are on some of Earnshaw's watches both before the interest of Wright elapsed and afterwards.

All the watches in this section have fusees, but the first is remarkable for the fact that the mainspring set-up is by worm and wheel, possibly a unique circumstance as far as chronometers are concerned, but then neither has this watch any temperature compensation.

The methods of temperature compensation of the watches varies considerably, cat. nos 59, 61, 67 and 69 have 'sugar tongs', cat. no. 62 has a single bimetal strip. The remaining watches have Earnshaw's balance also covered in the same patent of 1783.

At one stage in his career it was alleged that the success of Earnshaw's timekeepers was due to the high degree of superficial finish applied to the movements: he was originally trained as a watch finisher. Stung by this remark, Earnshaw for a time produced movements which he left virtually 'in the grey', or with the least possible amount of superficial finish and no gilding. Only the parts in working contact were properly finished and polished, and these are almost invisible except to the trained eye. Needless to say, such watches go every bit as well as those finished in the usual way, since the superficial finish contributes nothing to the performance. Two of the movements in the Museum's collection, cat. nos 61 and 63, illustrate this result of the touchiness of Earnshaw's character.

57 THOMAS EARNSHAW (1749–1829)

c. 1783

CHRONOMETER MOVEMENT *Plates 40b–f, 41a–b*

Signature: On the back plate 'Robert Tomlin Watch Maker to the King London No 1400'.

Dial and hands: Flat enamel dial with subsidiary seconds, Roman hour numerals and Arabic five minute numerals.

Minute hand not original, seconds hand missing.

Movement

Ebauche marks on the underside of the back plate (T.W over PT over 34.

Dial plate diam. 44·6 mm; front plate diam. 41·1 mm; back plate diam. 39·4 mm; frame h. 8·7 mm.

Frame: Full plate construction, turned pillars. No barrel bridge, unusual pierced and engraved balance bridge, balance potance with moulded edge. The brass parts gilded.

Fusee: With maintaining power having a brass ratchet wheel. Setting-up-work by worm and wheel under the barrel, an unusual feature in a chronometer.

Going train: Well made and finished, the brass wheels gilded and with a turned ring in the band of the wheel at the roots of the teeth on both sides. The pinions with deeply turned and polished undercuts, and the ends faced and polished. The pitch of the teeth rather coarse, especially the centre wheel and pinion.

Jewelling: Only the escapement pivots in pierced jewels with endstones. The jewels large and well made of pale ruby shot with darker colours, the endstones flat on both sides, the retaining screw heads and sinks conical.

Escapement: A very early form of Thomas Earnshaw's escapement. The detent mounting and adjustments similar to the illustration in Thomas Wright's patent. A screw in the edge of the back plate acts on the edge of the brass detent mounting, to move the detent towards or away from the balance staff. A tiny fine pitch screw on the back plate adjusts the height of the detent by acting on and bending the free end of the detent mounting. The tension of the detent spring towards the banking is also adjustable by a third screw set in the block on which the foot is mounted. By screwing in this screw and slightly releasing that holding the detent, the tension against the banking can be increased.

The escape wheel not sunk for lightness but of remarkably thin section, and gilded, mounted on a turned brass collet. Polished steel impulse roller, slightly countersunk at the centre, with a poising hole opposite the impulse notch. The impulse face leaning slightly towards a radial at the tip. The discharge jewel fitting into a dovetail in the roller, and with a depth adjustment by the head of a screw set in the roller. The roller also drilled for a brass pin also apparently for setting the depth but later abandoned. The detent somewhat deteriorated but probably original, with a gold passing spring pinned into a block, and a steel locking pin later filed and now having draw, forming part of the detent. A steel peg for banking against the inside of a steel screw head, with obvious signs of rust around the point of contact.

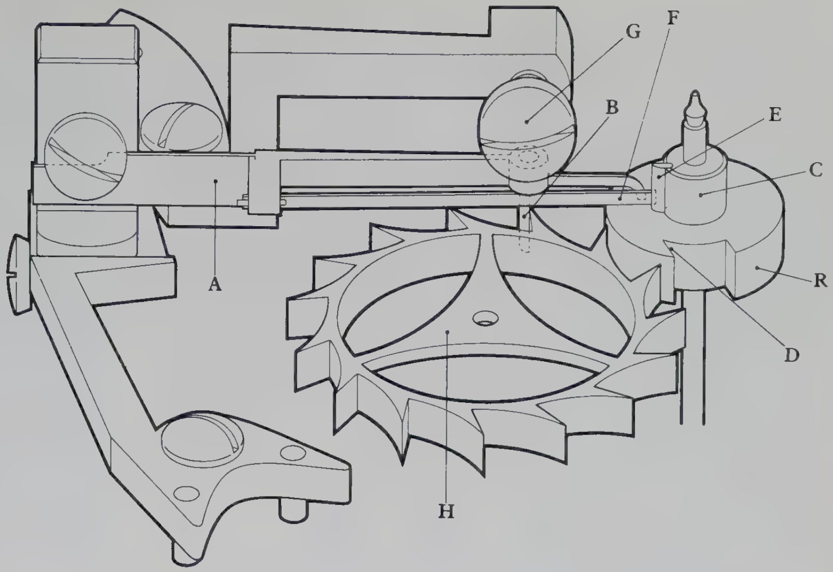


FIGURE 4
Thomas Earnshaw's spring detent escapement

A	detent
B	locking stone
C	discharge roller
D	impulse face of roller
E	discharge jewel
F	passing spring
G	banking screw
H	escape wheel
R	impulse roller

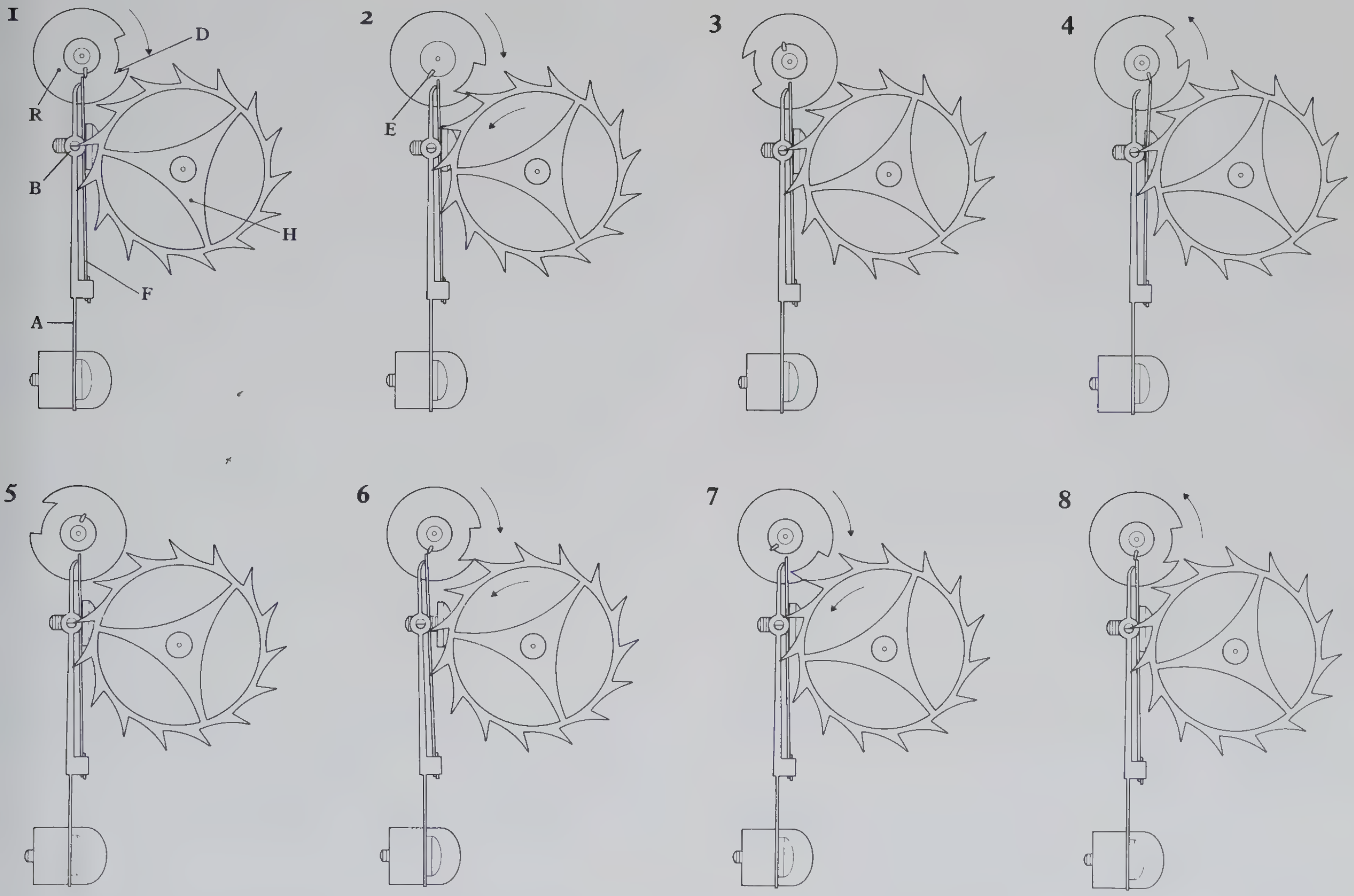


FIGURE 4A
Sequence of operations of Thomas Earnshaw's spring detent escapement

1 Escape wheel H about to be unlocked. Discharge jewel E is picking up passing spring F and moving detent A aside
2 Escape wheel giving impulse to face D on roller R
3 Supplementary action occurring with detent having locked wheel again
4 Passing action occurring as passing spring F is moved aside by discharge jewel E
5 Balance about to return from its maximum excursion
6 Detent unlocked, escape wheel tooth about to drop on to impulse face D of roller R
7 Impulse about to end
8 Discharge jewel E just about to pick up passing spring F

Balance: Plain steel three-armed balance, the crossings of triangular section, once polished but now deteriorated. Diam. 21·0 mm, h. 0·85 mm.

Balance spring: Polished and blued steel spiral balance spring of 7 open turns, pinned to an overhanging stud. The cock carries a well-polished index held by a brass ring with two screws. The spring projects through the stud for a quarter of a turn and so may not be original. There is no sign of there having been any thermal compensation.

Going-train counts:
Great wheel (fusee) 49 teeth
Centre pinion 12 leaves, wheel 60 teeth, 6 arms
Third pinion 8 leaves, wheel 64 teeth, 6 arms
Fourth pinion 8 leaves, wheel 70 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 15 leaves, minute pinion 18 leaves
Hour wheel 60 teeth, minute wheel 54 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Goebel in 1932 (reg. no. CAI-1752).

Note: Thomas Earnshaw's patent for his escapement and early bimetallic balance, No. 1354, was taken out for him by Thomas Wright in May 1783. In order to recover the costs of taking out this patent it was agreed between Wright and Earnshaw that the latter should make and sell watches to other watchmakers purchasing the right to use the escapement for £25. Each watch that Earnshaw made could be signed in the name of the purchaser but was required to bear a stamp for which a fee of one guinea was payable to Wright. This watch signed *Robert Tomlin* is one of two examples known that is stamped in this way and made under this particular agreement. The other named *Jessop Southampton* is no. 19 and is in the Time Museum, Rockford U.S.A. Eventually the agreement must have lapsed, and Earnshaw made a number of watches signed by other makers which do not carry the stamp or any other indication to connect them with Wright.

Bibliography: A. G. Randall, 'An Early Pocket Chronometer by Thomas Earnshaw signed Robert Tomlin', *AH*, June, 1984.

58 THOMAS EARNSHAW

c. 1795

MARINE CHRONOMETER *Plate 41c–d*

Signature: On the back plate 'Tho^{s} Earnshaw Inv^{t} et Fecit No 245'. On the barrel bridge 'London No 2264'. On the dial 'THO^{S} EARNSHAW LONDON INV^{T} et FECIT No 245'.

Box: The movement contained in a brass canister, gimballed in a later mahogany box. The dial plate fits into a turned sink in the open end of the canister with two pins projecting upwards into holes in the dial plate at XII o'clock and VI o'clock. The bezel with raised glass is threaded on the outside of the canister and secures the dial plate. There is a brass levelling weight fixed rather crudely with a single screw to one side of the wide turned ring at the bottom of the canister. The winding hole is covered by a brass plate on a brass strip across the bottom and with an overhanging arm to prevent the strip being pulled away from the bottom more than just enough to clear the winding hole. The gimbal ring is solid and pivoted in screws set in massive brass brackets held with screws in the sides of the box. In opposite corners of the box wooden blocks for brass strips are fixed loosely under screws so that they can be swung out to press against the bottom of the canister, thus locking the gimbal system. A simple key fits in a hole in one of the blocks.

The box has a glazed panel in the top under a hinged lid with push-piece catch, loose handles and a lock with inlaid brass escutcheon plate. It is otherwise plain but polished, with a strip of red velvet as a dust seal between top and bottom, glued to the bottom. Box 186 mm square, h. 195 mm.

Dial and hands: There is no separate dial. The engraving is directly on the dial plate, and is filled with black wax, the surface grained and silvered.

Blued steel hands, the seconds riveted to a boss on a brass pipe.

Movement
Dial plate diam. 76·4 mm; front plate diam. 62·5 mm; back plate diam. 61·9 mm; frame h. 14·8 mm.

Frame: Built like a large watch movement, full plate construction with a detachable barrel bridge and five turned pillars. Four of the pillars are in the usual places round the edge of the movement, riveted to the front plate and with pins to retain the back plate except the one over which the balance passes which has a recessed screw. Set in from the edge, between the fusee and the escape pinion is a fifth plain turned pillar, pinned to the front plate and with a recessed screw at the back. There is a large dust-excluding tube over the winding square fixed to a wide foot held with two screws on the back plate. The brass parts are finished dull grained.

Fusee: Fitted with the usual stop-work and maintaining power, the steel work grained or dull polished, the setting-up-work on the dial side of the front plate. The later mainspring signed 'George Cotton and Sons Jan 1937', with solid hooking in a slot in the barrel wall. The barrel arbor is not snailed.

Going train: The wheels riveted to their pinions, the latter with the acting part of the leaves and the pivots polished. The ends of the pinions and the arbors left grained.

Jewelling: Only the pivots of the escape arbor and balance staff in pierced jewels, with endstones flat on both sides except the diamond endstone set in a polished steel ring in the balance cock. The front pivots of the third and fourth arbors run in brass bushes set like jewel settings, each held with two screws (c.f. Brockbank's no. 632, cat. no. 74).

Escapement: Earnshaw spring detent escapement with typical brass escape wheel, the arms sunk well below the level of the teeth and rims, the leading edges of the teeth slightly indented but more by compression than cutting and indicating a heavy 'drop on' at the beginning of the impulse. The impulse roller jewel set leaning towards a radial to the distinctly rounded tip. There is a considerable gap in the roller in front of the jewel indicating the provision for a heavy 'drop on' at the beginning of impulse. Remarkably large diameter discharge roller with the tip of the jewel almost at the same radius as the impulse roller. The straight detent planted well inside a tangent to the tip of the locked tooth, with a gold passing spring held under a screw head and a well-made triangular locking stone leaning slightly backwards. The detent foot is pinned and held with a screw to the underside of the back plate, and banks against the inside of the head of a brass screw set in the usual brass overhanging piece.

Balance: Typical Earnshaw bimetallic two-armed balance with segment-shaped brass weights each held with a screw on the inside. Brass timing and quarter screws. Diam. of rim 28·4 mm, h. 3·22 mm.

Balance spring: Helical steel spring of dull dark-grey appearance, of 5 full turns, with a long terminal curve of slightly more than one turn to the brass collet and a shorter one of about half a turn to the stud. The balance cock is double and the stud screwed to the edge of the overhanging part of the lower one.

Going-train counts:
Great wheel (fusee) 64 teeth, groove with $6\frac{1}{2}$ turns
Centre pinion 14 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 65 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 12 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves (brass)
Hour wheel 42 teeth, minute wheel 42 teeth.

Provenance: Ilbert Collection; in his inventory notebook Ilbert states that he acquired this chronometer in 1952 from 'Plum' (i.e. The 'Plumber') a nickname for Malcolm Gardner (reg. no CAI-1960). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Exhibited: 'Pendulum to Atom' under the auspices of The Worshipful Company of Clockmakers at Goldsmiths' Hall, London, October 1958.

Bibliography: Cedric Jagger, *The World's Great Clocks and Watches*, London, 1977, pp. 181, 182; Bertele 1981, p. 157.

59 THOMAS EARNSHAW
1800

CHRONOMETER *Plate 41e–f*

Signature: On the back plate 'T. Earnshaw Inv^{t} et Fecit No. 504', on the barrel bridge 'LONDON 3163'.

On the dial below the figure XII 'THOMAS EARNSHAW INV^{T} ET FECIT N^{o} 504'.

Case: Silver pair cases with the London hallmark for 1800 and the maker's mark T.C. surmounted by an axe, the mark of Thomas Carpenter. Outer case diam. 60·2 mm, h. 19·6 mm, with five-knuckle hinge; inner case diam. 52·0 mm, h. 25·0 mm, over glass.

Watch paper in case back.

Dial and hands: Flat enamel dial, similar in appearance to that of cat. nos 63 and 65.

Gold hands also similar in appearance to those of cat. no. 65.

Movement
Dial plate diam. 47·4 mm; front plate diam. 42·9 mm; back plate diam. 42·4 mm; frame h. 7·5 mm.

Frame: Similar full plate construction to most other watches by Earnshaw. The brass parts gilded, the steel parts well finished and blued. The movement retained in its case by a single positioning peg in the dial plate, and two screws going through the inner case and into the dial plate. One frame pillar shortened flush with the back plate and with a screw to retain the back plate, to allow free movement of the sugar tongs assembly for mean time regulation. Cock engraved with scrolling foliage and a flower. Scratched on the dial plate 'John Hill Taunton 1852 FHV Taunton Feb^{y} 1839'.

Fusee: Similar to cat. no. 63 except that the steel parts are prepared and finished to a high standard. The barrel arbor with an extended square at both ends, the barrel itself without a flange but waisted at the lower end to miss the teeth of the great wheel; this done after gilding. Blued steel maintaining detent returned by a piece of brass wire pointing downwards from a hole in the back plate.

Going train: The third and fourth wheels gilded, the ends of the pinions and the arbors finished and polished as well as the pivots and acting parts of the pinions.

Jewelling: The pivots of the escape pinion arbor and balance staff only in pieced jewels with endstones. The endstone in the balance cock a piece of ruby set in a blued steel disc.

Escapement: Apparently as originally fitted in every detail and similar to cat. no. 63. On the impulse roller only the impulse face polished.

Balance: Steel three-armed balance, polished on both sides, triangular section arms. Diam. 25·0 mm, h. 0·55 mm.

Balance spring: Dull, blued steel, flat, open coiled spiral spring of $7\frac{1}{3}$ turns, without overcoil or terminal curve and pinned to a brass stud on the back plate.

Thermal compensation: Sugar tongs bimetallic strips mounted on a brass plate with central open boss held with two blued steel screws in the hole in the back plate concentric with the balance axis. The edge of the brass plate having a pointer moving over an engraved sector on the edge of the back plate for mean time regulation. Each bimetallic strip carries an index pin at its extremity embracing the last turn of the balance spring. The two index pins move towards each other in heat and apart in cold.

Going-train counts:
Great wheel (fusee) 62 teeth, worn and leaning backwards
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Webster in 1930 (reg. no. CAI-1733).

Note

1. The watch paper is of J. Greenhatch, Manchester, and written on the reverse 1496 over March 45 and a dollar sign with an extra vertical stroke.

60 THOMAS EARNSHAW

c. 1800

MARINE CHRONOMETER *Plate 42a–e*

Signature: On the back plate 'Thos. Earnshaw Inv^{t} et Fecit No 509'. On the barrel bridge 'London No 2853'. On the dial 'Thos Earnshaw INV^{T} ET FECIT No 509 ONE DAY'.

Box: Rectangular mahogany box with two brass carrying handles, locking lid with round glazed aperture in the top and mahogany sliding cover. The inside of the box lined with green baize, except for two triangular wooden (oak?) inserts to front right and rear left corners which have brass spring locking pieces screwed to them. The lid also has a brass slide which limits the opening to slightly more than vertical. One small empty hole in the front of the lower case. Ivory disc recess in the front of the top but with the engraved(?) disc now missing. The sliding cover is made from a darker mahogany veneer than the rest of the case and has been made from two pieces with different grain pattern. The underside of this cover is lined with dark purple leather. One key to lock, and one winding key. The corners of the base are dovetail jointed. Brass gimbal mountings carrying a brass canister which houses the movement. Sides 198 mm square, base 208 mm square, overall h. 176 mm.

Dial and hands: Silvered brass dial. Scratched on the back '509' and 'JB 2/6/86'. Dial attached to movement by two screws which pass through the front plate and screw into the back of the dial. One screw now missing.

Movement
Dial plate diam. 76·1 mm; dial plate th. 5·1 mm; front plate diam. 62·9 mm; back plate diam. 60·2 mm; frame h. 16·3 mm.

Frame: Similar to cat. no. 58 except that there is no dust-excluding tube for the winding arbor. The balance potance has a moulded edge to the foot.

Fusee: Similar to cat. no. 58. The maintaining detent is returned by a piece of steel wire set in a hole in the back plate and pointing down. The barrel is waisted at the closed end to miss the great wheel, and the rectangular hole for the original solid mainspring hooking has been carefully filled. The present mainspring, unsigned, is hooked by hook and eye at both ends.

Going train: Similar to cat. no. 58.

Jewelling: Similar to cat. no. 58, but without any separate bushes for the train pivots.

Escapement: Similar to cat. no. 58 but with a brass escape wheel of thirteen teeth, showing signs of marking on their acting faces. The discharge roller is smaller in proportion. The gold passing spring is pinned in a block on the side of the detent. The foot of the detent overlaps the edge of the back plate, and banking is against a steel screw.

Balance: Similar to cat. no. 58, riveted to a brass collet, but without the brass poising screws; the arms a different shape. The steel part of the bimetallic rim blued. Diam. of rim 28·0 mm, h. 2·8 mm.

Balance spring: Later closely coiled blued steel helical spring of 11 turns, with terminal curves, pinned to a brass collet, and stud on the balance cock.

Going-train counts:
Great wheel (fusee) 63 teeth, groove of $6\frac{3}{4}$ turns
Centre pinion 14 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 13 teeth, 4 arms
Beats per hour: 15,600

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves, brass
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the purchase of this chronometer in 1931 from Lilley & Son (reg. no. CAI-1957). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Bibliography: Britten 1982, p. 222, pl. 139a and b.

61 THOMAS EARNSHAW

1800

CHRONOMETER *Plate 43a–c*

Signature: On the back plate 'Tho^{s} Earnshaw Inv^{t} et Fecit No 506'. On the barrel bridge 'LONDON 2849'. On the dial 'THOMAS EARNSHAW INV^{T} ET FECIT N^{O} 506'.

Case: Gold pair cases both with the London hallmark for 1800 and the maker's mark T.C. with an axe above (c.f. cat. no. 59). Outer case diam. 58·0 mm, h. 16·7 mm, inner case diam. 51·4 mm, h. 20·6 mm. In the case a watch paper bearing the arms of Charles George Perceval, Baron Arden (1756–1840).

Dial and hands: Enamel dial with slightly curved edge faintly signed on the back, in red in the enamel 'Earn 5'.
Gold hands.

Movement
Dial plate diameter 47·7 mm; front plate diam. 42·9 mm; back plate diam. 41·5 mm; frame h. 7·5 mm.

Frame: Similar construction to cat. no. 59 but finished as cat. no. 63. The movement held in its case by one positioning pin and two screws through the side of the case into the gilded dial plate. The back plate retained by pins except the pillar near the regulator sector which has been shortened so as to be flush with the top of the plate and fitted with a screw. All the screws left grey and apparently not hardened and tempered. The dust-excluding tube missing, the retaining hole visible near the winding square.

Fusee: Similar to cat. no. 63, the barrel arbor with an mounted, square only on the end under the dial carrying the spring of ratchet wheel.

Jewelling: Only the pivots of the escape pinion, third and fourth wheel running in pierced jewels with endstones. The endstone in the balance cock a piece of ruby set in a steel ring. The endstones rarely flattened on their outer surfaces.

Escapement: Original Earnshaw detent escapement similar to cat. no. 63. The detent locking stone is [illegible] polished steel and is of small diameter and short length. The brass escape wheel with slight signs of wear.

Balance: Steel three-armed balance, polished on both sides, mounted on a brass collar on the balance staff. Diam. 23 mm, h. 0.57 mm.

Balance spring: Blued steel flat spiral spring of 7 open turns without overcoil or terminal curve fitted under the balance and pinned to a brass stud screwed to the back plate.

Compensation: Sugar tongs (see cat. no. 59).

Going-train counts:
Great wheel (fusee), 60 teeth, worn
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Earl of [illegible], then Ilbert Collection, purchased by Ilbert at Christie's sale, 12 July, 1933, lot 4 (reg. no. CAI-[illegible]).

Note: This watch is in almost perfect mechanical condition, and is a good example of its kind with sugar tongs compensation. Although the working surfaces are well finished, the minimum of effort has been expended in finishing the rest of the movement.

62 THOMAS EARNSHAW

c. 1800

CHRONOMETER MOVEMENT *Plate 43d*

Signature: On the back plate 'Thos Earnshaw Inv' et Fecit No 598'. On the barrel bridge 'London 3041'.

Dial and hands: None.

Movement
Front plate diam. 42.75 mm; back plate diam. 41.6 mm; frame h. 7.6 mm.

Frame: The dial plate with the movement hinge is missing; there was no dust cover. Otherwise similar to cat. no. 59.

Fusee: Similar to cat. no. 59.

Going train: Similar to cat. no. 59.

Jewelling: Only the pivots of the escape pinion and balance staff in pierced jewels with endstones. The endstone in the balance cock a ruby set in a blued steel ring.

Escapement: Originally an Earnshaw detent escapement was fitted as in cat. no. 63. Later the original detent and brass fixing arm and the brass banking piece were removed, all the holes for these are now empty. At some time a [illegible] detent and brass clamping block were fitted, the brass block being still in place. The escapement is now a Chinese duplex. The steel screw in the edge of the back plate for adjusting the original detent fixing is still in place.

Balance: Plain polished steel three-armed balance. Diam. 25.15 mm, h. 0.51 mm.

Balance spring: Flat spiral steel spring, [illegible] turns and not blued, pinned to a gilded stud screwed to a plate on the back plate, the stud partly obscuring the number of the watch.

Thermal compensation: Remains of sugar tongs, see cat. no. 59.

Going-train counts: as originally fitted.
Great wheel (fusee), 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

The present six-leaf escape pinion and twelve-tooth escape wheel are later substitutes.

Motion work
Cannon pinion only remaining, 12 leaves.

Provenance: Ilbert Collection, purchased by Ilbert from Gould in 1931 (reg. no. CAI-1996).

63 THOMAS EARNSHAW

c. 1800

CHRONOMETER MOVEMENT *Plate 43e–f, 44a–b*

Signature: On the back plate 'Thos Earnshaw Inv' et Fecit No 657'. On the barrel bridge 'No 2760'. On the dial, centrally below the XII 'THOS EARNSHAW INV' ET FECIT 657'.

Dial and hands: Enamel dial with slightly curved edge.
Gold minute and hour hands, both damaged, the steel seconds hand with a pierced disc at the extremity of the long tail.

Movement
Dial plate diam. 51.2 mm; front plate diam. 46.6 mm; back plate diam. 45.7 mm; frame h. 8.5 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins. Detachable barrel bridge with turned relief around the hole for the barrel arbor pivot. The dial plate carrying the hinge attached to the front plate by three short pillars and pins. The case catch and return spring mounted on the front plate under the dial. The balance potence foot without the usual moulding. The dial plate only gilded, otherwise the frame left devoid of any gilding. The steel parts left whitish-grey in appearance.

Fusee: Keywind fusee with a dust cup fitted on the winding square. The usual stop-work and maintaining power, the maintaining ratchet wheel brass, the detent return spring a short piece of brass wire pointing down from a hole in the back plate.

The setting-up-work under the dial, the barrel arbor with an extended square at both ends.

Going train: The brass wheels ungilded, the steel pinions with polished leaves, but the ends of the pinions and the arbors left unpolished.

Jewelling: The pivots of the escape pinion arbor and the balance staff in pierced jewels with endstones. The endstone jewels flat on both sides. Diamond endstone in the balance cock set in a blued steel ring. All the other pivots in holes in the brass frame.

Escapement: Typical Earnshaw detent escapement with brass escape wheel, sunk out on the upper side and with characteristic tooth form, the teeth showing signs of wear on the leading edges. The impulse roller left grey except for the polished impulse face, which also shows signs of wear. The usual jewelled discharge roller. The detent appears to be original, the end of the spring clamped against a brass block by a steel screw. This block is riveted to a brass arm and the latter screwed and steady pinned to the underside of the back plate, but overlapping slightly the edge of the plate. A steel screw set in the edge of the back plate can be used to move the detent towards or away from the balance centre by causing the brass arm to bend. The gold passing spring is pinned in a hole in a block integral with the detent body. Banking for the detent is provided by the head of a brass screw set in a separate brass banking piece also screwed and steady pinned to the underside of the back plate. The escape wheel teeth are locked on a polished flat on a steel pin set in the detent. The pin is set so that there is draw between the flat and the wheel teeth, tending to hold the detent in the locked position.

It is unusual for a detent such as this to survive because in order to remove and replace it in the watch it is best not to disturb the detent where it is clamped since this will disturb the initial adjustment, but rather to remove the whole detent and block assembly. This is so delicate and difficult to do that the detent is frequently broken, whereupon the whole assembly is discarded and replaced by a new detent with solid foot fixed directly to the underside of the back plate.

Balance: Bimetallic two-armed balance with brass segment weights fixed by screws from the inside. The timing screws at the ends of the arms are probably original but the other four screws set in the bimetallic rims probably later additions when the watch was re-sprung. The steel parts of the bimetallic rims blued. Diam. of rim 19·2 mm, h. 1·73 mm.

Balance spring: Blued steel helical spring of 6$\frac{1}{2}$ turns with terminal curves, free sprung to a gold stud on the balance cock and a brass collet on the balance staff. At the time that this watch was made Earnshaw was not using hardened and tempered steel wire for his balance springs. Such springs caused a gradual slowing down of the rate, so it is not unusual to find them replaced by a hardened and tempered spring. In this instance the addition of screws to the balance would seem to indicate that the spring has been replaced although the extra screws could be required because the spring was shortened for some reason.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Jauncey in 1934 (reg. no. CAI-1592).

64 THOMAS EARNSHAW

1805

CHRONOMETER MOVEMENT *Plate 44c–d*

Signature: On the back plate 'Tho^{s} Earnshaw Inv^{t} et Fecit 808'. On the barrel bridge '3816'. On the dial, in the upper half below the figure XII 'THOMAS EARNSHAW INV^{T} et fecit N^{o} 808'.

Dial and hands: Enamel dial, the edge curved, similar to cat. no. 63 and cat. no. 65.

The hands are missing.

Movement

Dial plate diam. 47·4 mm; front plate diam. 42·9 mm; back plate diam. 41·9 mm; frame h. 8·53 mm.

Frame: Similar to cat. no. 63. No movement hinge, case catch or spring has ever been fitted to the dial plate. The movement was secured in its case by a positioning peg and two screws through the case middle and into the dial plate radially.

Fusee: Similar to cat. no. 63, a brass dust-excluding cap is held on the winding square by a polished steel screw.

Jewelling: Only the pivots of the escapement in pierced jewels with endstones. The outer surface of the endstones curved.

Escapement: Only the brass escape wheel remaining, the leading edges of the teeth slightly damaged. Originally the escapement would have resembled that of cat. no. 63. The brass arm to which the detent was fixed is still in place, also the adjusting screw set in a slot in the edge of the back plate, and the detent banking.

Balance: Missing, it would probably have resembled that of cat. no. 63.

Balance spring: Probably pinned to a stud on the balance cock, both are missing. There is no indication that there was an index.

Going-train counts:
Great wheel (fusee) 60 teeth, worn

Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, brass minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Ash in 1932 (reg. no. CAI-1595).

65 THOMAS EARNSHAW

1807[1]

CHRONOMETER MOVEMENT *Plate 45a–d*

Signature: On the back plate 'Tho^s Earnshaw Inv^t et Fecit 866' the 8 an upside down ampersand sign, the 6 partly obscured by a screw. On the barrel bridge 'London'. On the dial centrally below the XII 'THO^S EARNSHAW INV^T ET FECIT No. 866.

Dials and hands: Enamel dial with slightly curved edge, similar to cat. nos 59, 63, and 66, chipped and cracked near XII. There is a faint circle on the dial passing through the minute dots, visible only with a strong lens.

Gold minute and hour hands, blued steel seconds hand with a long tail, riveted to its pipe.

Movement
Dial plate diam. 49·7 mm; front plate diam. 43·0 mm; back plate diam. 42·0 mm; frame h. 7·63 mm.

Frame: Similar to cat. no. 63, but the dial plate much wider than the front plate to accommodate the overlapping barrel. The hinge has been torn from the dial plate. Both frame and dial plate gilded but not much on the front plate under the dial. The steel parts hardened and tempered, and finished to the usual English standard. The balance potance with a moulding at the outer edge of the foot.

Fusee: Similar to cat. no. 63, the steel parts prepared and finished as for those of the frame.

Going train: The third and fourth wheels gilded, the arbors and pinion ends finished and polished.

Jewelling: Similar to cat. no. 63, but the endstone in the balance cock a piece of clear sapphire set in a blued steel ring.

Escapement: The brass escape wheel may well be a replacement as the teeth are not of the usual form. Instead they are narrow and stand almost radially off the rim of the wheel. The impulse and discharge rollers are similar to cat. no. 63. The original detent and brass arm removed and replaced by a detent with gold passing spring, jewelled and with solid foot, the retaining screw for this covering part of the last 6 of the engraved number on the back plate. The original holes for the two steady pins and screw for the brass arm are visible by the end of a pillar at the end of the signature.

Balance: Inverted bimetallic balance with two steel timing screws and brass segment weights, the steel part of the rims blued. The free movement of the rims limited by brass pegs in the segment weights going into holes in rings at the end of a thin steel cross arm on the balance.

Diam. of rim 18·6 mm, h. 1·65 mm.

Balance spring: Flat blued steel spiral spring under the balance, free sprung without overcoil to a stud in the back plate by the third arbor pivot hole. The collet of brass.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, brass minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Benson in 1935 (reg. no. CAI-1593).

Note

1. No. 867, which is similar, is in a silver pair case dated 1807 by the Chester hallmark on the inner case.

66 THOMAS EARNSHAW

1807

CHRONOMETER *Plate 45e–f*

Signature: On the barrel bridge 'Tho^s Earnshaw London 3469'. On the back plate 'Inv^t et Fecit 876'. On the dial 'THOMAS EARNSHAW INV^T ET FECIT N^o 876'.

Case: Gold pair cases, the inner with Chester hallmark (see Note) for 1807 and the maker's mark T.H.; scratched 876. The outer with the London hallmark for 1809 and the maker's mark W.M., also punched S and scratched 790, the five-knuckle hinge recessed flush with the edge of the case. Outer case diam. 59·4 mm, h. 18·0 mm. Inner case diam. 53·5 mm, h. over the glass 24·3 mm.

Dial and hands: Similar to cat. no. 61, the dial cracked across a diameter from II to VII. Signed 'THOMAS EARNSHAW INV. ET FECIT No 876'.

Gold hands.

Movement
Dial plate diam. 49·7 mm; front plate diam. 43·0 mm; back plate diam. 42·3 mm; frame h. 7·6 mm.

Frame: Similar to cat. no. 65 but with a hinge on the dial plate and case catch and spring on the front plate under the dial.

Fusee: Keywind fusee with stop-work and maintaining power, the maintaining power ratchet wheel brass. The barrel arbor with an extended square at both ends, the setting-up-work on the front plate under the dial. The barrel relieved at the lower end to miss the great wheel and without a flange at the upper end. All the steel parts well finished and blued.

Going train: The third and fourth wheels gilded, the ends of the pinions, the pinions and the arbors well finished and polished.

Jewelling: The pivots of the escape pinion arbor and balance staff only in pierced jewels with endstones. The endstone in the balance cock of clear sapphire set in a blued steel ring.

Escapement: Earnshaw detent escapement, the original detent and brass arm have been removed and replaced with a well-made detent with solid foot, screwed to the underside of the back plate. The original banking has been retained. The brass escape wheel is of the usual form (see cat. no. 63), the teeth slightly marked. The edge and radial impulse planes of the impulse roller have been polished, the other surfaces are grained. The discharge roller jewelled.

Balance: Bimetallic two-armed balance with timing screws set in the rims at the ends of the arms. Brass segment compensation weights, screws on the inside to secure them to the rim. The steel parts of the rims blued, their free movement limited by brass pegs set in the compensation weights going into holes in rings at the end of a thin white steel cross-arm. The cross-arm has a central boss sandwiched between the underside of the balance and a brass boss. Diam. of rim 18·6 mm, h. 1·53 mm.

Balance spring: Flat open coiled spiral steel spring of 7½ turns, dull blued and pinned to a gilded brass overhanging stud, screwed to the back plate.

Going-train counts:
Great wheel (fusee) 60 teeth, slightly marked
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, steel minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Selfridges in 1930 (reg. no. CAI-1732).

Note: Thomas Earnshaw's watch 872/3467 also has an inner case with a Chester hallmark.

67 ROBERT ROSKELL

c. 1810

CHRONOMETER *Plate 46a–d*

Signature: On the back plate 'R^t Roskell 5262'. On the barrel bridge 'Liverpool'.

Dial and hands: Flat enamel dial, secured to the dial plate by three feet and pins, marked on the reverse 'Cooper 72'. The circles on which the minute and second divisions are marked are scribed with a fine point.

The hands missing

Movement
Dial plate diam. 48·5 mm; front plate diam. 44·6 mm; back plate diam. 43·6 mm; frame h. 7·7 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by blued steel screws, detachable barrel bridge. The dial plate carrying the movement hinge, and attached to the front plate by three feet and pins. The case catch and spring mounted on the front plate under the dial. No dust cover or provision for one. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, all the steel parts blued. The maintaining ratchet wheel of brass, the steel detent set well in from the edge of the frame. A dust cup on the winding square. The setting-up-work on the front plate under the dial, the barrel arbor with an extended square on that end only.

Going train: A well made but quite standard train and layout. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: All the pivots of the going train and escapement arbors in pierced jewels, including the fusee, those of the escapement with endstones. A diamond endstone set in a blued steel ring on the balance cock.

Escapement: A spring detent escapement showing some similarity to Thomas Earnshaw's work. The three-armed escape wheel made of steel, and without the usual sunk out central portion, but with all surfaces black polished. The solid foot detent is presumably a later replacement, it has a steel passing spring pinned into a block in a similar way to Earnshaw's detents. There are three holes filled with brass plugs near the detent but not in the usual places for the adjustable brass foot of an Earnshaw detent, and there is no provision for the adjusting screw in the edge of the back plate (see cat. nos 59, 61 and 62). The locking stone is made from a half round piece of ruby, and the detent banking provided by the head of a steel screw set in a gilded brass piece with a foot screwed and pinned to the underside of the back plate.

The steel impulse roller polished on the bottom edge and crescent, and with a small rounded boss towards the balance, set with a jewel leaning heavily towards a radial to the tip. The leading edges of the escape wheel teeth only slightly marked. The usual jewelled discharge roller without an adjusting flat, polished on the bottom and edge.

Balance: Plain steel three-armed balance, the arms and both sides polished, mounted on a brass collet on the balance staff. Diam. 24·4 mm, h. 0·62 mm.

Balance spring: Open coiled spiral spring, poorly made, of 6¼ turns, without an overcoil or terminal curve, pinned to a polished steel stud overhanging the balance, and round brass collet.

Thermal compensation: Sugar tongs compensation with two bimetallic arms screwed and pinned to a gilded brass plate. The brass plate has a pointer moving over a scale for mean time adjustment, and a central pierced boss concentric with the balance staff held in a hole in the back plate by two polished steel screws.

Going-train counts:
Great wheel (fusee) 60 teeth (worn)
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Bennet in 1942 (reg. no. CAI-1749).

Note: This movement shows remarkable similarity to those of a series made by Thomas Earnshaw (cat. nos 59, 61 and 62). The layout of the parts, particularly on the back plate, also closely resembles these. The pillars were probably prepared to retain the back plate by pins, the marks are still visible on the back plate, suggesting that a standard ébauche was used.

68 STEPHENSON AND FARROW

c. 1820

CHRONOMETER MOVEMENT *Plate 46e–f*

Signature: On the barrel bridge 'Stephenson and Farrow LONDON 1073'. On the dial STEPHENSON AND FARROW LOMBARD ST.[1]

Dial and hands: Flat enamel dial, attached by a peg and screw in the edge of the dial passing into holes in the short flat dial feet. The circle and divisions marked and divided with a scriber. On the dial STEPHENSON AND FARROW LOMBARD STREET.

Gold minute and hour hands, the seconds hand missing.

Movement

Dial plate diam. 48·3 mm; front plate diam. 42·1 mm; back plate diam. 40·9 mm; frame h. 8·5 mm.

Frame: Full plate construction with four turned pillars, two having provision for pins and two for blued steel screws to retain the back plate. A detachable barrel bridge. No dust cap or ring or provision for one. The dial plate carrying the movement hinge secured to the front plate by three countersunk headed screws under the dial. The case catch and hinge mounted on the front plate under the dial. Note that the dial plate is considerably wider than the front plate, and compares with Earnshaw watches cat. nos 65 and 66.

All brass parts gilded.

Fusee: Keywind fusee without provision for a dust guard round the winding square. The usual stop-work and maintaining power, with a steel maintaining ratchet wheel, and the maintaining detent return spring a short piece of wire set in a screw pointing down from the back plate and passing into a small hole in the detent. Setting-up-work on the front plate under the dial, the barrel arbor with an extended square on that end only. The barrel without a flange.

Going train: Well-made and finished conventional train and layout. The brass wheels gilded, the steel pinions and arbors well finished and polished. The centre pinion with turned and polished undercuts on both sides.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A diamond endstone set in a blued steel ring on the balance cock.

Escapement: A typical Thomas Earnshaw detent escapement except for the dovetailed detent. The brass escape wheel with arms sunk out below the level of the rim and teeth, and tooth form of characteristic shape and finish. The top and bottom of the wheel with polished or burnished finish. The steel impulse roller with polished bottom, edge and shallow V-shaped notch. The impulse surface leaning towards a radial to the tip. The usual jewelled polished steel discharge roller.

The dovetailed detent held by a single screw in a brass block, with an adjusting screw for the movement of the detent towards or away from the balance axis. An integral arm carries a banking screw in a slotted hole, banking the detent against the end of the threaded part of the screw. The remains of the detent with a gold passing spring riveted on, and a half-round ruby locking stone, possibly all a replacement for the original.[2]

Balance: Typical Thomas Earnshaw bimetallic balance, see cat. no. 66. The steel part of the rims blued, brass segment weights secured by screws from the inside, and blued steel cross-arms to limit the inward movement of the rims with brass pegs set in the weights passing into rings on the ends of these blued steel arms. The central boss joining the arms sandwiched between the balance and brass pins driven into the brass collet on which the balance is mounted. Brass timing screws set in the rims at the ends of the arms. Diam. of rim 18·4 mm, h. 2·9 mm.

Balance spring: Blued steel helical spring of 6 turns, with terminal curves, free sprung to a polished steel stud on the balance cock and a shaped brass collet.

Going-train counts:
Great wheel (fusee) 62 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1931 (reg. no. CAI-1751).

Notes

1. Britten 1982 lists D. W. Stephenson and J. Farrow 1820–3 at 27 Lombard St, London, and Stephenson and Farrow 1810–24 at the same address.
2. It seems likely that the escapement and balance were made by Thomas Earnshaw sen. or jun.

69 THOMAS EARNSHAW

c. 1810

MOVEMENT WITH DUPLEX ESCAPEMENT *Plate 47a–b*

Signature: On the barrel bridge 'Earnshaw London'. On the back plate the number 1785.

Dial and hands: Flat enamel dial with Roman hour numerals and subsidiary seconds dial, attached to the dial plate by two feet. The hole in one foot fitting onto a peg projecting inwards from the edge of the dial plate, the other diametrically opposite, held by a screw going into the edge of the dial plate from outside.

Red gold spade hour hand and tapered minute hand, the latter having a round hole adjusted flush on to the end of the cannon pinion. The seconds hand missing.

Movement
Dial plate diam. 48·0 mm; front plate diam. 42·7 mm; back plate diam. 39·6 mm; frame h. 7·4 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, detachable barrel bridge. The wide dial plate secured to the front plate by three screws under the dial, the dial plate carrying the movement hinge. The case catch and spring mounted on the front plate under the dial. The frame and dial plate gilded. The dust-excluding ring and the retaining dog screws are now missing, the holes for these screws visible on the edge of the back plate.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheels brass. The barrel arbor with an extended square on both ends, the setting-up-work on the front plate under the dial, the setting-up click partly under the minute wheel.

Hand setting: The hands were originally set to time from the back. An arbor pivoted in the frame near to the hinge had an extended square to take the key. On the other end, under the dial, a pinion connected with the motion work via an intermediate wheel. The arbor, the pinion and the intermediate wheel are now missing.

Going train: The wheels gilded, the pinions and arbors polished. The train a very unusual count as a result of the fourth wheel with fifty-seven teeth.

Jewelling: The fourth arbor lower pivot and those of the escapement in pierced jewels, the escapement with endstones also. In the balance cock a diamond endstone set in a polished steel plate.

Escapement: Duplex escapement with light brass wheel and steel impulse pallet and roller. The roller a replacement for the original ruby roller.

Balance: Ungilded brass three-armed balance. Diam. 22·2 mm, h. 1·0 mm.

Balance spring: Dull blued steel spiral spring of 7 open turns, above the balance, pinned to a brass stud on the balance cock.

Thermal compensation: Well-made sugar tongs compensation with an adjusting screw for the separation of the index pins. The brass block carrying the bimetallic strips screwed to a brass carriage held under a bridge graduated 0–10, with teeth on the edge indexed by a worm for mean time adjustment. The graduated scale concentric with the balance rim is presumably for checking the balance amplitude, or perhaps for some other regulator later discarded.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 57 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 17,100

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1296).

70 THOMAS EARNSHAW

c. 1810

MOVEMENT WITH DUPLEX ESCAPEMENT *Plate 47c–d*

Signature: Around the edge of the back plate 'Tho^{s} Earnshaw 119 High Holborn LONDON' and 'N^{o} 4922'. On the enamel dial below the figure XII Tho^{s} Earnshaw No. 4922'.

Dial and hands: Enamel dial slightly curved at the edge, with Roman hour numerals and sunk subsidiary seconds. The hour and minute hands missing, the seconds hand of blued steel, probably later.

Movement
Front plate diam. 43·7 mm; back plate diam. 39·5 mm; frame h. 6·2 mm.

Frame: Three-quarter plate with three turned pillars, the back plate retained by marked blued steel screws. No dial plate, the dial attached directly to the front plate by three feet and pins. The frame gilded. Separate bridges under the dial on the front plate for the third and fourth arbor lower bearings, and for the escapement lower bearings.

Fusee: Keywind fusee with stop-work and maintaining power, the maintaining ratchet wheel of steel. The setting-up-work under the dial in a recess in the front plate.

Going train: The wheels gilded, the pinions well finished with arbors and pivots polished. The fourth wheel turned away after gilding to miss the underside of the escape wheel.

Jewelling: Only pivots of the escape pinion arbor and balance staff in pierced jewels with endstones. Diamond endstone in a blued steel ring in the balance cock.

Escapement: Duplex with single light brass wheel, polished steel impulse pallet and ruby roller.

Balance: Earnshaw type of bimetallic two-armed balance with brass segment compensation weights and screws set in the rims at the ends of the arms. The steel parts of the rims blued. The compensation weights only just clear the stud and index pins. Diam. 15·4 mm, h. 1·8 mm.

Balance spring: Dull blued steel spiral spring of $8\frac{1}{2}$ turns without overcoil or terminal curve, pinned to a steel stud on the balance cock. Regulation by an index passing under the stud on the balance cock.

Balance cock: Provision appears to have been made to plant the balance cock flush with the back plate by using the three empty steady pin holes in the front plate by the pillar where the back plate is cut away. One of the dial feet comes through what would have been the retaining screw hole.

Going-train counts:
Great wheel (fusee) 78 teeth
Centre pinion 12 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth
Hand set wheel 24 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1298).

II.vi (cat. nos 71–117)

THE USE OF THE EARNSHAW FORM OF SPRING DETENT ESCAPEMENT BY OTHER MAKERS

In this section are included all the marine and pocket chronometers based on Earnshaw's original plan. They illustrate the gradual evolution and development of the escapement. Thomas Earnshaw mounted his detents on a brass piece with an adjusting screw to move the detent towards or away from the baance. He also used a half-round steel locking pin and a steel passing spring. Other early makers, such as Robert Pennington, favoured a detent with a foot dovetailed into a brass block, adjustable towards or away from the balance, a steel passing spring and the locking stone devetailed into its setting. Later a locking stone of triangular or half-round section set into a pipe was preferred, and the steel of the passing spring was replaced by gold. The 'solid foot' detent screwed directly to the underside of the back plate gradually replaced those with adjustment. The amount of finishing and polishing increased until some detents were made which were black polished on all visible surfaces.

One of the most remarkable aspects of the development of the detent escapement is in the proportioning of the parts. The ratio of impulse roller diameter to escape wheel diameter could be varied over a wide range. The acting length of the detent was also the subject of much research to determine the most suitable length in relation to the escape wheel diameter and to the radius of the tip of the discharge jewel.

If the ratio of impulse roller diameter to escape wheel diameter is taken the significance is as follows: the larger the impulse roller diameter for a given escape wheel diameter, the smaller the angle of lift, and so the smaller the apparent disturbance to the balance during the transmission of impulse. Unfortunately this is accompanied by a very shallow intersection of the wheel teeth with the impulse jewel so that all the tolerances are more critical, and if sufficient impulse is to be transmitted a greater driving force is required. Conversely if the impulse roller diameter is reduced for a given escape wheel diameter, the angle of lift is increased and the free motion of the balance is disturbed over a greater arc. The driving force can be correspondingly reduced but there is a greater likelihood of the escapement setting (and the chronometer thus stopping) if the balance amplitude is suddenly reduced by external disturbance. A good working rule is that for box chronometers the impulse roller diameter should be equal to the radius to the tips of the escape wheel teeth, and for pocket chronometers slightly greater because the risk of setting is greater. This is assuming that the escape wheel has the usual fifteen teeth. The desirable proportions will be different if other numbers are used.

Similar arguments apply to the choice of the length of the acting part of the detent. The larger this is, the smaller the angle through which it must move in order to unlock the escape wheel teeth, but the greater the mass and inertia of the detent, and the greater the effect of lack of poise and the danger of bouncing against its stop. Conversely the shorter the detent the greater the unlocking angle, but the less the effects of mass, inertia, out of poise and bouncing against the stop. A good compromise is that the length of the acting part of the spring detent from the locking stone to the shoulder of the spring at the foot should be about 1·1 times the diameter to the tips of the escape wheel teeth. Of this about one-third should be occupied by the spring and the remaining two-thirds by the blade. (The subject of the proportioning of the parts of a detent escapement is dealt with by Claudius Saunier in *Treatise on Modern Horology*, see Bibliography). One of the most interesting conclusions that can be drawn from the examples in the collection is that there was no movement toward settled values for these proportions, and that most makers constantly experimented with different values. This is at variance with the statements made by Saunier, Glasgow, Frodsham, Britten and others who give definite conclusions as to the values chosen either by themselves or others. Of the forty-seven items in this section only two, cat. nos 83 and 115, have going barrels, and each has two barrels. Of the remainder, thirty-seven have ordinary fusees and eight having reversed fusees, these latter are cat. nos 71, 81, 82, 92, 108, 110 and 111. Twelve of the examples are marine chronometers, namely cat. nos 71, 73, 74, 81, 82, 83, 87, 91, 92, 99, 109 and 110.

Bibliography: Such is the diversity of examples in this section that there is no general book that is relevant, except as stated above for the subject of the proportions of the chronometer escapement.

71 EARDLEY NORTON

c. 1790

MARINE CHRONOMETER *Plates 47e–f, 48a–b*

Signature: On the dial 'E NORTON LONDON'. On the back plate '2322'.

Box: The movement contained in a brass drum rigidly fixed inside an octagonal mahogany base. A brass bezel overlapping the base fits on the outside of the drum and is secured bayonet fashion, it has a bevel-edged flat glass. It is now imposible to remove the brass drum from the base, but tapped holes coming through the side of the latter may have been for the pivoting points of a gimbal ring. There are also two brass securing screws in the base. The dial plate fits flush in a recess in the top of the drum, with a positioning peg. Box 148 mm across the flats, h. 78 mm overall.

Dial and hands: Slightly domed enamel regulator dial attached to the dial plate by the two small screws on the edge. There is no sign of scribed divisions under the enamel of the minute and seconds markings.

Gold hands, hour hand not original.

Movement

Dial plate diam. 139 mm; front plate diam. 108·4 mm; back plate diam. 108·4 mm; frame h. 30·1 mm.

Frame: Full plate construction with four baluster pillars, the back plate retained by pins. The dial plate, with pierced centre to clear the motion and under dial work, attached to the front plate by four pillars and pins. It is of much larger diameter than the front plate and appears once to have been fitted with a case catch and hinge, various holes remaining. The balance staff passes through the frame and is pivoted on the front plate and in a pierced bridge on the back plate. There are a number of unused holes, including a corresponding pair in the plates near their edge, beside the fourth wheel, with a cock on the front plate, possibly for a train or balance stop device, and one in a pillar which is threaded.

Fusee: Reversed fusee fitted with the usual stop-work and maintaining power. The barrel is of unusually large diameter and made from a piece of strip bent and soldered and the bottom soldered on. The setting-up-work is planted on the back plate with a very short extended arbor square on that end for setting up. The mainspring is grained white and not blued, it is not signed but punched with the figure 3 at the end, and hooked with hook and eye to both the solid unsnailed arbor and the barrel wall. The fusee has a single winding click and a brass maintaining wheel, the detent and the stop arm are fitted with brass return springs.

Going train: The wheels riveted to the steel pinions; these, their arbors and the pivots polished.

Jewelling: Only the pivots of the escape pinion arbor and balance staff in pierced jewels with flat endstones crudely set in strips of brass. The pierced jewels curved towards the endstones and with a sink on both sides.

Escapement: Spring detent escapement of Earnshaw type but of massive proportions. The brass escape wheel sunk out on one side with only the tips of the teeth left the full thickness. The grained steel impulse roller set with a jewel leaning towards a radial to the tip. The discharge roller of brass, with an adjusting flat and a jewel set in a hole breaking into the edge. The detent straight except for the foot set sideways and screwed to a brass arm on the underside of the back plate. There was once an adjusting screw set in a slot in the edge of the back plate acting on the brass arm to move the detent towards or away from the balance axis. This screw has broken off and the arm is now fixed with two screws. The passing spring is steel, held under a screw head and the detent slotted for a flat locking stone. Banking for the detent is provided against a screw head set in a brass bracket screwed to the underside of the back plate.

Balance: Bimetallic two-armed balance similar to the Arnold 'z' type with the rim sections screwed to integral blocks on the ends of the cross bar. There are steel timing screws at the ends of the arms and similar compensation screws set tangentially in brass blocks screwed to the free ends of the rims. The balance is riveted to a brass collet on the staff. Diam. of rim 39·9 mm, h. 4·3 mm.

Balance spring: Blued steel spiral spring of about $5\frac{3}{4}$ turns, without an overcoil or terminal curve, free-sprung to a brass stud on the back plate under the balance. Pinning to the stud is by a square pin in the square hole and to the collet by a wedge-shaped pin in a slot in the edge of the ring-shaped brass collet.

Going-train counts:
Great wheel (fusee) 48 teeth
Centre pinion 12 leaves, wheel 64 teeth, 4 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 56 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves (held by a pin through the arbor), minute pinion 14 leaves
Hour wheel 56 teeth (held by a pin through an arbor pivoted in the frame), minute wheel 42 teeth

Provenance: Ilbert collection; Ilbert states that he acquired this chronometer from Clowes in 1937 (reg. no. CAI-1940). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Exhibited: British Clockmakers Heritage Exhibition, Science Museum, London, May–September 1952; British Watches and

Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954.

Bibliography: Bertele 1981, p. 150.

72 BROCKBANK

c. 1798

CHRONOMETER *Plate 48c–d*

Signature: 'No 919 Brockbank's London'. On the dial below XII, 'BROCKBANKS LONDON'.

Case: Later continental silver case, by the marks, probably Russian, with fixed dome, the glazed bezel and back hinged to the middle, the joint broken. No push-pieces in the pendant or fly springs in the case. Diam. 55 mm, h. over glass 21·5 mm.

Dial and hands: Flat enamel dial similar to cat. nos 149 and 150. The divided circles for minutes and seconds scribed with a sharp point, the divisions applied in enamel afterwards. The dial secured to the dial plate by three feet and pins.

Flat gold minute and hour hands probably not the original, the seconds hand missing.

Movement

Dial plate diam. 49·5 mm; front plate diam. 46·7 mm; back plate diam. 44·0 mm; frame h. 7·3 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins, detachable barrel bridge. The dial plate carrying the movement hinge secured to the front plate by three radial screws in the edge. The case catch and spring on the front plate under the dial. The back plate slotted for the detent, the former has broken and been repaired as a result of being weakened by this process. The balance potance very small and with an unusually small foot. The escape wheel pivoted between the back plate and a potance passing into a rectangular hole in the front plate but screwed and steady pinned to the underside of the back plate. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power. The maintaining ratchet wheel steel, the detent spring passing over the edge of the great wheel. The barrel arbor squared on the lower end only, the setting-up-work mounted on the front plate under the dial.

Going train: It is unusual for a pocket chronometer to have a 14,400 beats per hour train. This is produced by the escape wheel of twelve teeth. The 60:1 ratio between the centre and fourth arbors is achieved in an unusual way, the fourth pinion having more leaves than the third. The wheels are all nicely gilded, the pinions well polished and finished. The face of the centre pinion is polished in a similar way to those of Josiah Emery.

Jewelling: The pivots of the escape arbor in pierced jewels, those of the balance in pierced jewels with endstones. The balance potance endstone set in a wedge-shaped slip of brass, that in the balance cock a diamond set in a polished steel ring.

Escapement: Earnshaw type of spring detent escapement with flat steel twelve-teeth escape wheel, the radiused backs of the teeth only polished. The wheel mounted on a brass collet. The detent with divided return spring screwed to the end of a brass block, itself screwed and pinned to the underside of the back plate. The short steel passing spring screwed on, its free end resting against the upstanding end of the detent horn. Ruby locking stone with two flat surfaces at right angles, joined by a radius. The detent banked against a steel screw set in a steel plate screwed to the upper side of the back plate. The steel impulse roller with radial jewel, the whole resembling a John Arnold impulse roller. The steel discharge roller slotted to take a projecting rectangular discharge jewel with slightly rounded end. The detent planted with its centre line well inside a tangent to a locked tooth.

Balance: Plain steel three-armed balance polished on both sides, the underside of the rim filed for poising, held with two steel screws on a brass collet on the balance staff. Diam. 21·0 mm, h. 0·58 mm.

Balance spring: Open coiled spiral spring of $6\frac{1}{3}$ turns, pinned to an overhanging gilded brass stud, and to a round brass collet. Blued steel index on the balance cock, the pins projecting down through a slot in the overhanging portion of the cock.

Amplitude limiting device: Between the brass collet on the balance staff and the impulse roller, a brass ring is fitted with a projecting peg. A hole is drilled into the side of the clearance hole in the back plate for the balance, presumably for a corresponding peg to limit the balance amplitude to half a turn in either direction. This peg is missing, leaving the empty hole.

Going-train counts:
Great wheel (fusee) 68 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 10 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 12 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Wartski in 1930 (reg. no. CAI-1850).

73 WILLIAM HARDY

c. 1805

MARINE CHRONOMETER *Plates 48e–f, 49a–b*

Signature: On the balance cock and back plate 'W$^{\text{m}}$ Hardy LONDON N$^{\text{o}}$ 53 Inv$^{\text{t}}$ et Fecit'. On the dial 'W$^{\text{m}}$ Hardy LONDON Inv$^{\text{t}}$ et Fecit'.[1]

Box: The movement protected by a canister dust cover fixed with screws to the dial plate, and fitted in a brass drum with a threaded bezel and domed glass. The brass drum is gimballed in a mahogany box. An inset flush with the upper edge of the bottom part of the box has a large central hole for the gimbal ring, with two brass brackets in opposite corners for the pivoting screws, and a third bracket for the locking device fitted on top of the gimbal ring. A later tipsy key is housed in the fourth corner.

The box is fitted with carrying handles, a lock with inset oval ivory escutcheon plate, and has a sliding panel in the lid, the lid with a stop and hinge over a rectangular glazed aperture. The sides of the box are dovetailed. Box 184 mm square, h. 163 mm.

Dial and hands: Engraved, silvered flat brass dial, the engraving filled with black wax, recessed flush in the dial plate and retained by the two screws.

Blued steel hands, the hour hand soldered to a brass pipe, the seconds riveted to a boss on a brass tube.

Movement

Dial plate diam. 79·0 mm; front plate diam. 62·5 mm; back plate diam. 61·2 mm; frame h. 15·9 mm; overall h. of balance cock 27·1 mm.

Frame: Full plate construction with a detachable barrel bridge and four turned pillars, the back plate retained by pins. The dial plate made from a thick turned ring with a recess for the front plate, fixed by three screws under the dial. The balance cock is unusually high for the special balance.

Fusee: Fitted with the usual stop-work and maintaining power, and with a long dust-excluding tube on the winding arbor held with a single screw. The setting-up-work is fitted on the barrel bridge, the arbor having a square on both ends, and a solid boss slightly snailed. The mainspring solid hooked to the barrel wall, and signed 'Geo. Cotton Jan 1902'.

Going train: Well made and finished, the pinions and arbors polished, with well-turned undercuts. The inner end of the centre pinion polished integral with the arbor and without an undercut.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the fourth rear and escapement with endstones. A large diamond endstone in the balance cock, set in a polished steel ring.

Escapement: A development of Earnshaw's spring detent escapement. The gilded brass escape wheel of modern pattern, with rim and arms sunk below the level of the teeth. Both rollers are jewelled with narrow pieces of ruby, the impulse roller has a polished edge only and the impulse plane of the jewel is on a radial. The straight detent screwed and pinned to the underside of the back plate, with a gold passing spring held under a screw head, and a gold replacement for the locking stone. Banking is provided against a steel screw head set in a brass overhanging piece, the screw head built up with an extra brass washer.

Balance: Built up on a straight bar of steel held with screws on a brass collet on the balance staff. On the underside of the steel strip two thinner brass strips are fitted with a small clearance except at the ends where they are fixed with rivets. They also clear the balance staff. Two brass rods standing off the ends of the steel bar, parallel to the balance staff, carry brass timing screws and brass turned weights held with screws near their free ends. These weights can be rotated for poising the balance, or moved up or down to alter the amount of compensation; each has a steel clamping screw, and a brass poise screw to make fine adjustments to the poise. Bar l. 33·3 mm, w. 3·8 mm, h. 1·3 mm.

In heat the bowing of the bimetallic crossbar will cause the brass weights to move towards the balance axis, and vice-versa in cold. For a further description see Gould 1923, pp. 187 and 188, in which a similar balance, though differing slightly in detail, is described at length, and also Appendix I.

Balance spring: Blued steel helical spring of 9¾ turns with terminal curves at each end, pinned to a solid steel collet placed about midway between the balance and the top pivot. The upper terminal curve is pinned to a resilient steel stud. This has an extension at the free end set with a flat disc of clear sapphire or glass working between a pair of brass adjustable screws pointing inwards from a steel bracket screwed in a slot in the cock. The fixed end of the stud is screwed to the cock diametrically opposite the bracket, and has a shaped central portion to clear the balance staff.

The resilient stud and banking device is intended to quicken the long arcs which would otherwise be slowed as a result of centrifugal forces produced by the motion of the compensating weights causing the crossbar to flex.

Going-train counts:
Great wheel (fusee) 63 teeth, 7 turn groove
Centre pinion 14 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 15,750

The great wheel of 63 teeth is similar to, but slightly smaller than, that in Thomas Earnshaw, cat. no. 60. The centre pinions are also similar, although the pinion in this chronometer is slightly smaller.

Motion work:
Cannon pinion 14 leaves (held tight on the arbor by a washer and pin), minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1933 (reg. no. CAI-1958). Presented by Mr Gilbert Edgar C.B.E in 1958.

Exhibited: British Watches and Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954.

Note

1. Baillie 1951 records William Hardy as working from 1800 to 1830. He introduced his type of balance in about 1804 and received a gratuity of 30 guineas from the Society of Arts in 1805 for the invention, and so did not patent it. It is possible that he was aware of the middle temperature error of compensation and intended this balance to correct it. Britten records that Hardy was at 28 Coppice Row, Coldbath Sq., Clerkenwell and that he received 50 guineas and the gold medal from the Society of Arts. Hardy also devised a constant force escapement for clocks.

Bibliography: Bertele 1981, 171.

74 BROCKBANK

c. 1806

MARINE CHRONOMETER *Plate 49c–e*

Signature: On the back plate 'Brockbank's LONDON No 632 TWO DAYS'. On the dust cover 'Brockbank's LONDON No 632'. On the dial 'BROCKBANKS LONDON'.[1]

Box: The movement with a dust cover with bayonet fixing to the dial plate, contained in a brass drum, gimballed, in a fine brass-bound rosewood box of later date. The gimbal ring and movement drum can be locked, and the box is fitted with the usual lock, flush-fitting carrying handles, a glazed top with hinged lid and a brass inset disc in the front of the top. Set in the top edge of the bottom of the box where it meets the top is a thin tongue of wood fitting into a corresponding groove in the bottom edge of the top, to exclude dust from the interior of the box. A tipsy key in a corner bracket.

The brass drum containing the movement has a hinged bezel with a domed glass which snaps shut and in the base a spring-loaded escutcheon plate with eccentric winding hole, standing proud of the bottom. Box 181·5 mm square, h. 188·5 mm.

Dial and hands: Flat enamel dial fixed by three short feet axially drilled and tapped for small blued steel screws, in holes in the dial plate. Dial plate scratched 637. The divisions on the dial are engine divided with scribed marks under the black enamel. There is no reserve of going indication.

Flat gold hands, seconds hand screwed to its pipe.

Movement

Dial plate diam. 101·4 mm; front plate diam. 78·6 mm; back plate diam. 77·8 mm; frame h. 22·2 mm.

Frame: Full plate construction without a detachable barrel bridge, four turned pillars, the back plate retained by blued steel screws. The front plate fits into a turned recess in the dial plate and there are three equally spaced screws passing through the edge of the dial plate into the front plate. The balance potance has a moulded edge to the foot and there is a separate bridge on the front plate for the third, fourth and escape pinion arbor bearings. The front plate is not pierced for the third wheel. The balance potance with a figure 3 punched on the underside of its foot.

Fusee: Fitted with the usual stop-work and maintaining power. The stop-piece return spring is formed from a piece of blued steel wire, the maintaining detent and its spring polished. A bell-shaped dust excluder is fitted tight on the squared part of the fusee arbor. The setting-up-work is fitted on the back plate, the solid unsnailed barrel arbor with an extended square at both ends. The mainspring appears to be original and is solid hooked at its outer end to a slot in the barrel wall. The mainspring is signed 'Geo Ansell & Son' on the outside and '1806' on the inside, also 'Wm Creghill Aberdeen Aug '72'.[2]

Going train: Well made and finished, the wheels riveted to their pinions, with well-turned undercuts on both ends of each pinion, the leaves, arbors and pivots polished.

Jewelling: The pivots of the escape pinion and balance staff in pierced jewels with endstones. A diamond endstone set in a blued steel ring, in the balance cock. The fourth arbor pivots are carried in bushes set like jewel settings, these may be made from a different alloy to that of the frame.

Escapement: A development of Earnshaw's spring detent escapement with a steel escape wheel polished on both sides. The straight detent has a large triangular locking stone and a gold passing spring riveted on but held clear of the detent by a brass spacer. The foot of the detent is cylindrical and passes into a hole in a steel block screwed and steady pinned to the underside of the back plate. There is a lengthwise groove in the detent foot so that it can be clamped by a screw set in the block. Another groove, turned near the outer end for a flange-headed adjusting screw is also set in the block for adjustment towards or away from the balance. The steel block also has an extended overhanging portion with the detent banking screw set in the end. Beside the hole for the detent in the block is another similar, now empty. This was presumably for a separate passing spring which was never fitted or was removed when the present detent was fitted. There are also two empty tapped holes for clamping and adjusting screws for the absent passing spring.

The impulse roller is remarkably thick (1·87 mm) and polished all over except on the top surface. It is jewelled, the impulse jewel leaning towards a radial to the tip, and there is a poising hole opposite the jewel. The polished leading edges of the escape teeth are severely cut near their tips. The discharge roller has no adjusting flat and is jewelled in a straight-sided slot.

Balance: Bimetallic three-armed balance riveted to a brass collet. Limiting screws for the movement of the free ends of the bimetallic rims pass through clearance holes in the rims and into steel brackets integral with the arms. The outer sides of the rims are graduated with a series of inclined marks near their free ends. The brass compensation weights are fixed by a fitted plate, each with a screw and steady pin. Each weight has a brass screw set sideways on its outside, tangential to the balance; these are for fine adjustment of the compensation. Poising of the balance has been achieved by filing the undersides of the arms. Each steel timing screw set in the fixed ends of a rim has two holes in the end of the head instead of a screwdriver slot. Diam. of rim 29·7 mm, h. 2·17 mm.

Balance spring: Unevenly blued steel helical spring of $7\frac{1}{2}$ turns, with terminal curves, pinned in a square hole in poised brass collet. The overhanging adjustable brass collet is screwed and steady pinned with steel pins to the back plate. The clamp for the end of the spring is curved on the part touching the inside of the spring and flat on the other.

Going-train counts:
Great wheel (fusee) 90 teeth
Centre pinion 12 leaves, wheel 90 teeth, no crossings
Third pinion 12 leaves, wheel 80 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 12 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 17 leaves held on with a pin through the centre arbor, minute pinion 21 leaves
Hour wheel 63 teeth, minute wheel 68 teeth

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of this chronometer from the Royal

Observatory, Greenwich, on 6 December 1930 (reg. no. CAI-1954). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Notes

1. The firm of Brockbank's, probably John and Myles Brockbank, appears to have existed from about 1791 to 1835.

2. Baillie 1951 records a George Ansell, spring-maker in Moorfields 1791–1821, and that he had a son, also George, who worked in London from 1796 to 1825. A George Ansell is also listed in Pigot's *London Directry* of 1823 as a spring-maker at 22 Whitecross Place, Finsbury.

Bibliography: Bertele 1981, p. 174.

75 J. REID

c. 1810

CHRONOMETER MOVEMENT *Plate 50a–d*

Signature: On the back plate 'Ball Alley Lombard Street', in the upper half of the dial 'REID CHRONOMETER'.[1]

Dial and hands: Flat enamel dial secured to the dial plate by three feet and pins, 7 fired into the back.

Gold minute and hour hands, blued steel seconds hand.

Movement

Ebauche marks 22, 7, 8. The number 7 also punched on the underside of the back plate and on the balance potance.

Dial plate diam. 48·8 mm; front plate diam. 45·5 mm; back plate diam. 45·0 mm; frame h. 6·9 mm.

Frame: Full plate construction with detachable barrel bridge, four turned pillars, the back plate retained by blued steel screws. The dial plate secured by three feet and pins, and carrying the movement hinge. The case catch and spring on the front plate under the dial. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work on the barrel bridge, the barrel arbor with an extended square on that end only. The barrel with a flange on the cover end.

Going train: Typical construction, the brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with arms and rim sunk out below the level of the teeth. The steel impulse roller polished on the bottom and radial impulse face only. The jewelled steel discharge roller without an adjusting flat, and fitted between the impulse roller and the brass collet on which the balance is mounted. The detent somewhat resembling that for an Arnold escapement and fitted in a slot in the back plate. The locking stone made from a flat piece of ruby, the gold passing spring held by a single rivet. The detent foot steady pin in a hole in a round steel plate, with a screwdriver slot. This plate when turned moves the detent towards or away from the balance. Banking for the detent provided against another round steel plate set in a recess in the back plate and held by a central screw. Part of this plate is filed away leaving a thin wedge to contact the detent.

Balance: Bimetallic two-armed balance of Earnshaw type with brass segment weights held by brass screws from on top, and brass timing screws set in the rims at the ends of the arms. Diam. of rim 18·2 mm, h. 2·3 mm.

Balance spring: Blued steel helical spring of 6 turns, with terminal curves, free sprung to a polished steel stud on the balance cock, and a brass bar-shaped collet.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, brass minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

The brass wheels and minute pinion gilded.

Provenance: Ilbert collection; purchased by Ilbert from Malcolm Gardner in 1931 (reg. no. CAI-1747).

Note

1. Britten 1982 records a J. Reid at the address shown on the back plate between 1800 and 1816. Baillie 1951 gives him as James Reid 1789–1824 and mentions this watch.

76 CHARLES HALEY

c. 1810

CHRONOMETER MOVEMENT *Plate 50e–f*

Signature: On the barrel bridge: 'Cha^{s} Haley London $^{\text{P}}_{\text{AM}}$'.[1]

Dial and hands: Enamel dial with curved edge retained by three feet passing through both the dial plate and the front plate, and with pins on the inside of the front plate.

Gold minute and hour hands. The seconds hand steel, not original.

Movement

Ebauche marks: 20, 12.

Dial diam. 48·8 mm; dial plate and front plate diam. 47·1 mm; back plate diam. 42·7 mm; frame h. 7·8 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, detachable barrel bridge. The dial plate with curved edge fixed to the front plate by three screws accessible from under the dial, it serves only as a distance piece between the dial and the front plate. The movement hinge, case catch and spring are attached to the front plate under the dial. All the brass parts are gilded. The front plate cracked from the edge to the maintaining detent pivot hole.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel steel. The barrel arbor squared at both ends, the setting-up-work mounted on the front plate under the dial. A dust cup fitted in the winding square.

Going train: Arranged in the usual way, the wheels gilded, the pinions nicely finished and polished.

Jewelling: Only the pivots of the escapement arbors in pierced jewels with endstones. The endstone on the balance cock a ruby set in a polished steel ring.

Escapement: Earnshaw type of detent escapement, the escape wheel of a coppery colour.

The polished steel impulse roller not jewelled, with the impulse face leaning towards a radial from the roller centre to the tip. The steel discharge roller jewelled in the usual way. The dovetailed detent left in the grey, fitted with a gold passing spring riveted on, and a thin flat locking stone of pale ruby colour. The detent foot screwed to a block on the underside of the back plate, the banking screw also fitted to an extension of this block. The usual screw let into the block to limit the movement of the detent towards the balance is lacking and is replaced by eccentric peg on the end acting on the front end of the foot. Each time the detent is disturbed it must be carefully repositioned.

Balance: Bimetallic two-armed balance with brass segment weights each held by a polished steel screw from the top. The underside of each rim reduced in height, from the middle towards the free end, over which distance the segment weights can be moved. Diam. of rim 17·8 mm, h. 2·55 mm.

Balance spring: Blued steel helical spring of $4\frac{1}{2}$ turns, with terminal curves. The brass stud secured in a slot on the balance cock by a single screw. Steel collet on the balance staff.

Balance cock: The upper surfaces decorated with engraving; acanthus leaf and fierce mask motifs. A six-sided hole pierced near the balance bearings to give a view of the balance spring beneath.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 6 arms
Fourth pinion 8 leaves, wheel 70 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert in 1932 (reg. no. CAI-1603).

Note

1. Charles Haley, 7 Wigmore Street was made a Freeman of the Clockmakers Company in 1781 and died in 1825. He was a pioneer chronometer maker and was granted a patent, No. 2132, in 1796 for a constant force escapement. A watch fitted with this device is preserved in the Guildhall Museum, London. He was appointed by the Select Committee of the House of Commons to report on Mudge's timekeepers and application for a reward.

77 ROBERT PENNINGTON

(Camberwell 1780–1816)

CHRONOMETER *Plate 51a–b*

Signature: On the barrel bridge 'Pennington London $\frac{130}{596}$'.

Case: Plain silver consular case with the London hallmark for 1810 and the maker's mark T.G. Diam. 54·8 mm, h. over glass 24·3 mm.

Dial and hands: Flat enamel dial, the minute and second divisions appear to be engine divided with a scribing point under the enamel markings. Attachment of the dial to the dial plate by three short feet and pins.

Blued steel hands, the hour and second hands replacements, the minute hand possibly original.

Movement

Dial plate diam. 48·5 mm; front plate diam. 47·0 mm; back plate diam. 42·5 mm; frame h. 8·5 mm.

Frame: Full plate with detachable barrel bridge, four turned pillars, the back plate retained by pins. On the inside of the front plate 596. The dial plate attached to the front plate by three short pillars and pins. On the inside of the dial plate scratched 596. No provision for a case catch or hinge, the movement secured in its case by a radial peg in the edge of the dial plate at IX and a screw opposite. The brass parts gilded, little having found its way onto the front plate under the dial or inside the dial plate. A large dust-excluding pipe with oval foot of characteristic shape around the winding square. The balance potance with a shaped foot without the usual moulded edge.

Fusee: Keywind fusee with the usual stop-work. The maintaining power with brass ratchet wheel and a combined detent and return spring. The setting-up-work in a shallow sink on the front plate under the dial. The barrel arbor with an extended square at both ends, a brass setting-up ratchet wheel. The barrel without a flange at the cover end.

Going train: Well made and finished, the brass wheels gilded, the pinions and arbors polished.

Jewelling: The fourth arbor lower pivot in a pierced jewel, and those of the escapement in pierced jewels with endstones. A diamond endstone in a blued steel ring on the balance cock. The heads of the screws holding the balance lower bearing are filed away so that the bearings can be removed if they are undone half a turn.

Escapement: A development of Earnshaw's spring detent escapement. The very light gilded brass escape wheel with arms and rim sunk below the level of the straight-backed teeth. The steel impulse roller polished all over and with a radial impulse face. The steel discharge roller with a wedge-shaped jewel dovetailed in place, no flat for adjusting. The remains of the much repaired dovetailed detent set in a gilded brass block with an integral arm for the banking screw. The block screwed and steady pinned to the underside of the back plate, so that the axis of the detent lies inside a tangent to the locked tooth. The detent is banked by an eccentric screw in the side of the brass block limiting the movement of the detent foot towards the balance. A steel passing spring riveted on with one rivet.

Balance: Bimetallic two-armed balance with red-gold compensation and quarter screws, probably a replacement for the original Pennington balance (see cat. no. 78). Diam. 24·2 mm, h. 2·42 mm.

Balance spring: Duo-in-uno blued steel spring with an upper terminal curve, free-sprung to a brass stud on the balance cock and to a steel collet, probably fitted with the new balance.

Amplitude limiting device: Consisting of two pins set vertically in the balance arms, one on each side of the spring, limiting the free expansion of the balance spring if the amplitude increases beyond a certain limit.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

Provenance: Ilbert collection; purchased by Ilbert from Ash in 1932 (reg. no. CAI-1738).

Bibliography: Vaudrey Mercer, 'The Penningtons and Their Balances', *AH*, Spring 1981, pp. 514–22.

78 ROBERT PENNINGTON
c. 1810

CHRONOMETER *Plates 51c–f, 52a–b*

Signature: On the back plate and barrel bridge 'Pennington London 426'.

Dial and hands: Engine-turned silver dial with sunk subsidiary seconds, the figures printed on, attached by screws in the edge of the dial plate passing into rectangular feet soldered to the underside of the dial.

Red gold minute and hour hands, steel subsidiary seconds hand.

Movement
Dial plate diam. 51·2 mm; front plate diam. 45·8 mm; back plate diam. 43·6 mm; frame h. 8·1 mm.

Frame: Full plate construction with detachable barrel bridge, four turned pillars, the back plate retained by pins. A deep dial plate carrying both case catch and spring and the movement hinge. The dial plate attached to the front plate by three screws under the dial, and a positioning peg. Minute and second divisions marked on the upper surface of the dial plate which is considerably cut away to leave room for the repeating work. A large dust-excluding pipe with oval foot of characteristic shape around the winding square. All the brass parts gilded, with little on the front plate under the dial or on the inside surfaces of the dial plate.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass. The setting-up-work mounted on the barrel bridge, the barrel arbor with an extended square on that end only. The barrel with a flange on the cover end.

Going train: A well-made and finished train, rather smaller than usual and grouped towards the fusee to leave room for the repeating train and hammers. The brass wheels gilded, the polished steel pinions and arbors with rather small undercuts.

Jewelling: Only the fourth arbor lower pivot in a pierced jewel. The escapement arbor pivots in pierced jewels with endstones. A diamond endstone set in a polished steel ring on the balance cock.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with short straight-backed teeth left standing proud of the sunk-out rims and arms. The bottom of the wheel and tops and backs of the teeth burnished. The leading edges of the teeth and the outside of the rim left with the original fine cutter marks. The steel impulse roller with rounded polished impulse face leaning away from a radial. This face, the edge and bottom of the roller polished. Jewelled discharge roller, the jewel dovetailed in place, with two adjusting flats on the edge of the roller. A very light solid foot detent with steel passing spring held by a single rivet and the locking stone dovetailed in a slot. Banking for the detent provided by a gilded brass piece held by a blued steel screw in the middle, and with a blued steel plug carrying an eccentric peg passing into a slot in the end of the banking piece, and with a screw head for adjusting the banking.

Balance: Bimetallic 'Pennington' type of balance built up on a brass three-armed wheel. Two bimetallic rim sections screwed and pinned to blocks left standing on the edge of the brass wheel. Two large compensation screws set near the free ends of each rim. Four brass quarter screws acting also as a protection for the bimetallic rims. Their heads are outside and clear of the rims, the threaded portions passing through clearance holes in the rims and into tapped holes in the brass wheel. Scribing marks for the arms of the wheel are visible on the underside, the wheel is riveted to a brass collet on the balance staff. The steel parts of the rims blued. Diam. 23·0 mm, h. 2·0 mm.

Balance spring: Large diameter blued steel helical spring, of 4½ turns, with terminal curves, free-sprung to a brass stud head with a brass screw on the balance cock. The collet a brass bar with two holes to lighten it and a central boss left standing round the balance staff.

Repeating work: Half/quarter repeating work of typical Stogdon type. The train and hammers pivoted in the frame, the steel parts fitted on the front plate under the dial. The steel parts are well and robustly made and with a grained finish. There are no gongs or provisions for them on the movement, and there is no means of adjusting the throw of hammers. The watch was probably a dumb repeater against blocks on the inside of the case.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings

Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 64 teeth, 4 arms
Escape pinion 8 leaves, wheel 18 teeth, 4 arms
Beats per hour: 17,280

Motion work:
Cannon pinion 4 leaves, minute pinion 36 leaves
Hour wheel 36 teeth, minute wheel 48 teeth

Repeating train:
Great wheel 42 teeth, second wheel 36 teeth, third wheel 32 teeth, fourth wheel 30 teeth, fifth wheel 24 teeth

The pinions of 6 leaves each except the fly pinion of 8 leaves

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1953 (reg. no. CAI-1743).

Bibliography: Vaudrey Mercer, 'The Penningtons and Their Balances', *AH*, Spring 1981, pp. 514–22.

79 SIGNED ELLICOTT BUT MAKER UNKNOWN

1815

CHRONOMETER *Plate 52c–d*

Signature: On the back plate 'Ellicott'.
On the barrel bridge 'Royal Exchange LONDON 1021.'[1]

Case: Open face silver case with the London hallmark for 1815 and the maker's mark I.M. Pendant marker's mark IF. The glazed bezel and back shutting flush, the middle remaining as a narrow rim. Case lock spring operated by a push-piece in the flattened pendant, and with a fly spring to open the back. Diam. 60·75 mm, h. over glass 25·8 mm.

Dial and hands: Flat enamel dial, slightly cracked, with 'seconds' fired in red on the back, subsidiary seconds. The dial fixed to the dial plate by three short feet and pins. The signature not repeated on the dial.

Gold minute and hour hands not matching in colour, the steel seconds hand a replacement.

Movement
Dial plate diam. 53·0 mm; front plate diam. 49·0 mm; back plate diam. 45·3 mm; frame h. 8·1 mm.

Frame: Similar to cat. no. 85 but without dust ring or cover; the gilding pale. Note the dust tube and foot for the winding arbor.

Fusee: Similar to cat. no. 85, no return spring for the setting-up pawl on the barrel bridge. The maintaining ratchet wheel steel. The mainspring barrel without a flange at the cover end.

Going train: Similar to cat. no. 85, but the gilding pale.

Jewelling: Similar to cat. no. 84.

Escapement: Earnshaw type of detent escapement, the brass escape wheel similar to an English ratchet-tooth lever escape wheel, not sunk, presumably a replacement. The jewelled discharge roller mounted between the impulse roller and the balance. The impulse roller left grey, once jewelled with an impulse pallet leaning towards a radial from the roller centre to the tip. The impulse jewel replaced by a piece of polished steel.

The replacement detent in a slot similar to an Arnold escapement. Banking is provided by an eccentric plate and screw. The locking stone replaced by a half-round piece of steel.

Balance: Bimetallic two-armed balance with brass segment compensation weights and screws set in the rims at the ends of the arms. Diam. of rim 20·9 mm, h. 1·93 mm.

Balance spring: Blued steel helical spring of 7½ turns, and with terminal curves, free sprung to an adjustable overhanging stud. Brass collet on the balance staff.

Going train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth, both snailed

Provenance: Ilbert Collection; Ilbert purchased this watch from Hutchinson in 1935 (reg. no. CAI-1735).

Note

1. This watch is undoubtedly a fake with spurious signatures put on after gilding and the numbers not fitting Ellicott's series.

80 WILLIAM PICKMAN

c. 1810

CHRONOMETER MOVEMENT *Plates 52e–f, 53a–b*

Signature: On the barrel bridge: 'W^{m} PICKMAN LONDON 3165'.[1]

Dial and hands: Flat enamel dial, scribed rings for the minute and second circles with divisions marked under the enamel. The dial attached to the dial plate by three feet and pins.

Only the gold hour hand remaining.

Movement
Dial plate diam. 50·3 mm; front plate diam. 48·0 mm; back plate diam. 47·3 mm; frame h. 8·1 mm.

Frame: Full plate construction with detachable barrel bridge, four turned pillars, the back plate retained by pins. The dial plate, carrying the movement hinge and stamped GH, secured to the front plate by four short feet and pins, and with the punched letters G.H. on the underside. The case catch and spring on the front plate under the dial. All the brass parts gilded. The shape of the foot of the winding arbor dust guard and the balance cock should be compared with those of Robert Pennington, cat. no. 78. The balance potance has a straight moulded edge to the foot.

Fusee: Keywind fusee with the usual stop-work and maintaining power, brass maintaining ratchet wheel. Polished steel setting-up-work on the front plate under the dial, the barrel arbor with an extended square at both ends. The barrel with a flange at the cover end and a slight waist to clear the great wheel teeth.

Going train: Well made and finished, the brass wheels gilded, the pinions and arbors polished. The wheel counts do not correspond with either watch by Pennington (cat. nos 77 and 78).

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, all with screwed-in settings, those of the escapement with endstones. A diamond endstone set in a blued steel ring on the balance cock.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with small, almost straight-backed teeth, not sunk out, and possibly a later replacement as the collet overlaps the central boss. The impulse roller with edge and bottom polished, and set with an impulse pallet dovetailed in place. The impulse face of this pallet leans slightly away from a radial to its tip. The steel discharge roller also with a dovetailed jewel, and a single flat for adjusting. The detent of the dovetailed type, held by a single screw on the side of a steel block screwed and pinned to the underside of the back plate. Banking for the detent provided against a brass screw in an arm under the escape wheel, and integral with a block screwed and pinned beside the detent block. The foot of the detent very flat, the steel passing spring attached by a screw. The locking stone of large diameter (0·8 mm), with a flat ground on one end for locking, the other end protruding from the detent pipe to provide banking against the screw. The detent planted with its centre line well inside a tangent to the locked tooth.

Balance: Later 'Pennington YCC' type of balance similar to that of cat. no. 78, except that short brass segments are riveted to the inside of the bimetallic rim sections near their free ends. Each of these brass segments is drilled and slotted to take a single compensation screw. The steel parts of the rims are not blued. Diam. 25·0 mm, h. 2·2 mm.

Balance spring: Blued steel helical spring of large diameter with 4 turns, with terminal curves, free sprung to a brass stud on the balance cock and a bar-shaped brass collet with two holes to lighten it (see cat. no. 78).

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 6 arms
Fourth pinion 8 leaves, wheel 70 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1745).

Note

1. This watch shows so many points of similarity to the work of Robert Pennington as to justify the assumption that it was at least finished by him.

Bibliography: Vaudrey Mercer, 'The Penningtons and Their Balances', *AH*, Spring 1981, pp. 514–22.

81 BARRAUDS

c. 1815

MARINE CHRONOMETER *Plates 53c–f, 54a*

Signature: On the back plate 'Barrauds' Cornhill LONDON 2/670'.[1] On the dial 'BARRAUDS' LONDON 2/570'.[1]

Box: The movement contained in a brass bowl, gimballed, in a brass-bound mahogany box. The box contains a canvas tag marked C 793 and a crown with GR beneath. The brass bowl with a spring-loaded escutcheon plate in the bottom, with an eccentric winding hole, and a threaded bezel with a flat glass. A lock is provided for the gimbal ring and the brass bowl. The box has carrying handles, a lock with brass escutcheon plate, and a key to the lock. The top is glazed and provided with a hinged lid; it once had an ivory disc let into the front but this is now missing. The hinges are all stamped WT and S IMPROVED. A brass plate let into the lid matches the escutcheon plate over the lock. The lock stamped PATENT. A narrow strip of wood let into the top of the bottom part of the box fits into a groove in the bottom of the top when the box is closed, thus making a seal to help prevent dust entering the box. The box is recessed at the back to provide clearance for the gimbal ring and is 171·5 mm square, h. 182·5 mm.

Dial and hands: Silvered, engraved brass dial graduated for 24-hour indication, the engraving filled with black wax. The subsidiary seconds dial in the upper half, reserve of going shown by a disc through an aperture in the lower half. The dial plate is recessed to take the dial flush with the edge, where it is held by three countersunk screws.

Blued steel hands with bevelled top surface.

Movement

Dial plate diam. 91·0 mm; front plate diam. 77·8 mm; back plate diam. 77·5 mm; frame h. 19·7 mm.

Frame: Full plate construction with a high detachable barrel bridge, the back plate retained by blued steel screws. The dial plate is deeply recessed under the dial. The movement fitted into a deep recess in the dial plate from the movement side where it is held by three large brass screws passing into the front plate from under the dial. Accurate positioning is achieved by a small brass screw set in the outside of the front plate near the edge passing into a hole in the dial plate. There is a separate bridge for the third and fourth arbor lower bearings and the escapement is mounted in a separate frame screwed in a shallow recess in the back plate. This frame is built up on a brass disc with a large potance for the balance staff and escape arbor lower bearings and a cock for the balance staff upper bearing. A large curved chain guard extending across the frame is fixed to the underside of the back plate. The dial plate scratched 2/570 and FH 1117 on the edge.

Fusee: Reversed fusee fitted with Harrison's maintaining power and English stop-work. The maintaining detent is returned by a tapered piece of blued steel wire set in a screw and pointing down from the back plate. The maintaining wheel of brass. The turned brass block for the stop-work arm is held by a large blued steel screw, and the return spring for the arm follows the edge of the back plate and acts in a slot in the outer end of the arm (c.f. Barrauds' no. 982, cat. no. 82). Setting-up-work of blued steel is mounted on the barrel bridge, the barrel being considerably higher than the frame. The blued steel mainspring is signed but the signature is illegible, although it could be 'Catte 9″ 514'. The spring is hooked at its inner end to the solid unsnailed barrel arbor, and at its outer end to a steel hook in the barrel wall.

Going train: arranged with an intermediate wheel and pinion planted between barrel and fusee to go for eight days. A very well-made train with polished pinions and arbors, the fourth wheel mounted on a brass collet, the others riveted to their pinions.

Jewelling: Only the pivots of the escape pinion arbor and balance staff in pierced jewels with endstones. A diamond endstone set in a blued steel ring in the balance cock.

Escapement: A development of Earnshaw's spring detent escapement with a very light brass escape wheel and polished steel impulse roller, unjewelled, and with a convex impulse surface. The jewelled discharge roller, with an adjusting flat, fitted between the impulse roller and the brass collet on which the balance is mounted. The detent with D-shaped locking stone and steel passing spring is arranged in a slot in the escapement platform similar to that for an Arnold escapement, and banked on a brass plate secured by a single screw and with a slot for adjusting. The steady pin in the detent foot passes into a hole in a polished steel plate in the edge of the escapement platform, having a single screw to retain it and an adjusting slot so that the detent can be moved slightly, if required, towards or away from the balance centre. The style and finish of the platform and escapement suggests the work of Robert Pennington.

Balance: Bimetallic two-armed balance very carefully made, the steel parts blued, with brass compensation and quarter screws. Screwed to the rims at the fixed ends are short sections of brass extending behind the free end of the opposite rim. A quarter screw passes through a hole in the free end of each rim section and into the brass piece behind. This arrangement may be intended to provide banking for the rims in extremes of temperature or simply to protect them during handling.

The other two quarter screws are carried in brass tubes with a thinned slotted portion and riveted to the inside of the rims. Diam. of rim 22·0 mm, h. 2·4 mm.

Balance spring: Blued steel helical spring of 9 open coils, with terminal curves, pinned to a split brass collet with concave upper surface, and to a brass diamond-shaped stud held with a single screw on the balance cock. A brass pin is positioned in the balance cock to act as a banking for the tail of the stud and fix its position.

Going-train counts:
Great wheel (fusee) 70 teeth
Intermediate pinion 14 leaves, wheel 70 teeth, 6 arms
Centre pinion 14 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves (brass), minute pinion 12 leaves (brass)
Hour wheel 72 teeth, minute wheel 56 teeth

Up-and-down indicator: A brass pinion of 18 leaves meshes with a wheel of 54 teeth carrying a brass pinion of 18 leaves, meshing with another wheel of 54 teeth. The last wheel carries the engraved indicating disc on a cannon.

Provenance: Ilbert collection; purchased from the Royal Observatory, Greenwich, in 1930. According to the entry in Ilbert's notebook, it was recorded in their earliest ledger as 2/570, that No. 517 was purchased in 1821 and No. 589 in 1824. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1956).

Note

1. When first made this chronometer was probably numbered 670. Some time afterwards, it was rebuilt by the maker and given the number 2 over 670 1, and the engraving on the back plate appears to confirm this. A possible explanation for the incorrect number on the dial is that this is later and that a mistake was made.

Bibliography: Bertele 1981, p. 185.

82 BARRAUDS

c. 1820

MARINE CHRONOMETER *Plate 54b–e*

Signature: On the dial 'Barrauds' London 982'. The Admiralty arrow is engraved on the seconds dial and backplate.

Box: The movement contained in a brass drum with threaded bezel having a domed glass, the bottom with a turned sink for the spring-loaded escutcheon plate with offset keyhole. The gimbal ring has a lock to secure the brass drum either with the dial up, or inverted for winding. Square-section mahogany box relieved to clear gimbal ring, the glazed top having a hinged lid with catch, fitted with handles and a lock, and in the lid front an inset ivory plaque engraved 'BARRAUDS 982 EIGHT DAYS' and an Admiralty arrow. In the lid an inset brass cross, and for the lock in front a brass escutcheon plate. Around the top of the bottom section the remains of some green material once stuck on as a seal, the underneath of the box similarly protected. The return spring for the offset cover plate missing. Also screwed to the inside of the lid a brass label holder with a card label 'ISSUED from Royal Observatory Greenwich 2 JUN 1921'. A counterweight to balance the inner case. Key to lock and winding key missing. Box 173 mm square, h. 177 mm.

Dial and hands: Engraved, silvered brass dial, the engraving filled with black wax, secured to the dial plate by three screws. The dial plate is recessed to take the dial and there is a positioning peg and corresponding notch in the edge of the dial at XII o'clock.

Blued steel hands, the minute and hour hands probably not original, although the beetle pattern hour hand is of fine quality. The seconds hand not original. The reserve of going indication is by an engraved silvered brass disc visible through an aperture in the lower half of the dial.

Movement

Dial plate diam. 120·4 mm; front plate diam. 89·3 mm; back plate diam. 89·0 mm; frame h. 40·0 mm.

Frame: Half plate construction with three turned pillars, the backplate retained by blued steel screws. The third and fourth arbors of the going train, and the escapement, mounted in a separate frame screwed and steady pinned to the front plate. The balance cock and a chain guard around the balance are both mounted on the top of this frame. The dial plate is deeply recessed under the dial for the motion work. Three large brass screws are used to fix the movement into a large recess in the other side of the dial plate. A smaller screw set in the edge of the front plate acts as a positioning peg in a slot in the dial plate. The sub frame is composed of two approximately semicircular plates separated by three turned pillars retained with blued steel screws.

Fusee: Large reversed fusee fitted with Harrison's maintaining power, a brass maintaining ratchet wheel and English stop-work. The fusee has 17 turns. Setting-up-work consisting of a large brass ratchet wheel and click, mounted on the back plate. A red brass dust-excluding pipe fitted on the back plate over the winding square which is also fitted with a squared brass cup. The maintaining detent is returned by a straight piece of blued steel wire set in a screw and pointing down from the back plate. The turned brass block for the stop-work arm is held by a large blued steel screw, and the return spring for the stop-work arm acts on the edge of the back plate in the slotted outer end of the arm. The later mainspring signed 'Geo. Cotton $\frac{9}{901}$', i.e. September 1901. The solid barrel arbor is not snailed, the outer end of the mainspring is hooked to a peg in the barrel wall.

Going train: No intermediate wheel and pinion fitted, the great wheel meshing directly with the centre pinion. A well-made train, the brass wheels riveted to their pinions, the latter well finished and polished.

Jewelling: Only the pivots of the escape pinion arbor and balance staff in pierced jewels with endstones. A diamond endstone set in a blued steel ring in the balance cock.

Escapement: A development of Earnshaw's spring detent escapement, with a brass escape wheel and polished steel impulse roller, unjewelled, with a polished radial impulse face. The discharge roller jewelled with a narrow wedge-shaped jewel, and with an adjusting flat. A dovetailed detent with gold passing spring held under a screw head, mounted in a brass block with integral arm for the banking screw in a slotted hole. A separate screw is provided to limit the movement of the detent towards the balance. It is set sideways in the brass block for the detent and has part of the threaded portion against which the detent foot rests half filed away.

Balance: Bimetallic two-armed balance, the steel parts blued, fitted with brass segment weights secured by screws from the inside. Two pairs of tapped holes are provided near the free ends of the rims, one pair being filled with small brass screws. There is also a pair of slotted brass timing nuts on blued steel screws set in the rim at the ends of the balance arms. The balance is held by two screws on a brass collet on the staff. Diam. of rim 27·6 mm, h. 3·4 mm.

Balance spring: White steel helical spring of 10 turns, with terminal curves, pinned to a split collet and diamond-shaped brass stud.

Going-train counts:
Great wheel (fusee) 120 teeth
Centre pinion 10 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 64 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour 14,400

Motion work:
Cannon pinion 14 leaves (brass), minute pinion 18 leaves (brass)
Hour wheel 54 teeth, minute wheel 56 teeth

Up-and-down indicator: A pinion of 10 leaves on the fusee arbor meshes with a three-armed brass wheel of 180 teeth screwed to the indicator disc.

Provenance: Ilbert Collection; Ilbert purchased this chronometer from the Royal Observatory, Greenwich, in 1930 and notes that according to their earliest records it was issued to *Shamrock* in 1824. It was entered for the first Premium Trial of 1822 but was unplaced for a prize. (No. 957 won the first prize of £300.) Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1939).

Bibliography: Cedric Jagger, 'Paul Phillip Barraud, 1750-1929', *AH*, London, 1968, p. 134.

83 BREGUET ET FILS

c. 1820

CHRONOMETER *Plate 55a–e*

Signature: On the dial 'BREGUET ET FILS No 4652'.

Case: Brass box,[1] the bezel friction tight on the box.

Dial and hands: The dial possibly not original, an engraved brass plate, heavily silver-plated, the plating peeling at the edges, secured by 2 screws to the front plate. The engraving filled with red wax.

Blued steel hands.

Movement

Front plate diam. 59·5 mm; front plate th. 4·5 mm at the edge; overall frame h. over the barrel cocks 15·0 mm.

Frame: The frame built up with cocks on both sides of the massive front plate. The brass parts gilded, the steel screws on the back blued and on the front left polished. The movement was originally secured in its case with three screws, now missing, and a positioning peg. It is now held in place by the front glazed bezel and with a single peg to position it.

Going train: Laid out in a straight line, the centre arbor offset. Two going barrels each fitted with Breguet stop-work allowing four turns of going, and each meshing with the offset centre pinion. The going-train wheels lodged under the dial to allow the maximum space for the two mainspring barrels and the balance. The centre and fourth pinions have the unusual numbers of 11 and 9 leaves respectively.

Jewelling: The third arbor rear pivot and both fourth arbor pivots in pierced jewels. The escape wheel and balance pivots in pierced jewels, with endstones set in steel plates.

Escapement: Earnshaw type of spring detent escapement. The impulse roller with an inset polished steel pallet, the acting surface leaning towards a radial from the roller centre to the tip of the pallet. The single-bladed detent with very thin foot secured under a brass plate by two screws on the block carrying both detent and banking, and with a brass passing spring held by a screw to an integral block on the detent. The banking provided by an eccentric plate held by a single locking screw. The locking stone made from a piece of cylindrical ruby, 0·55 mm diam., the exposed acting part ground to a triangular shape. The grained steel discharge roller mounted between the impulse roller and balance, with two semicircular grooves to enable it to be gripped and turned, and set with a jewel for unlocking. Brass four-armed escape wheel, the teeth of the shape used by Thomas Earnshaw.

Another detent operated by an eccentric headed screw, to hold up the escape wheel so that the balance can be removed without damage to the wheel.[2] The acting detent must, of course, be removed before the balance is removed.

Balance: Bimetallic two-armed balance, the steel parts blued, with quarter screws on the studs fixed in the rims, secured to a steel collet by two screws. Diam. of rim 20·1 mm, h. 2·31 mm.

Balance spring: Blued steel helical spring free sprung to a stud under a steel plate on the balance cock and to an elaborate counterpoised brass collet. The spring with $9\frac{1}{4}$ turns without terminal curves. The middle turns of the spring thinned so that they expand and contract much more than those at the ends.

Going-train counts:
Great wheels (barrels) 108 teeth each
Centre pinion 11 leaves, wheel 75 teeth, 5 arms
Third pinion 10 leaves, wheel 72 teeth, 4 arms
Fourth pinion 9 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work
Cannon pinion 12 leaves (hollow, snap on), minute pinion (steel) 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth, both polished brass

Stop-work
Driving wheels 12 teeth each, driven wheels 10 teeth each

Provenance: Ilbert Collection; purchased by Ilbert from the firm of Breguet in 1931 (reg. no. CAI-1721).

Exhibited: La Chaux-de-Fonds, May–September 1976 (see exh. cat., p. 40).

Notes

1. The Certificate No. 2780 issued on 7 April 1931 does not give the date of manufacture of the movement. It simply states that the brass box was made by Colonel Brown himself in 1914, and the timekeeper sold to Mr C. A. Gilbert. The movement is stated to have two barrels, a detent escapement, silver dial and a brass box, and to be old.
2. A marine chronometer by Breguet, Neveau and Cie, No. 5053, is described by L. Appleby in *AH*, March 1965 (pp. 298, 299). This, too, has a train locking device but it acts on the fourth wheel.

84 ELLICOTT
1820

CHRONOMETER *Plate 56c–d*

Signature: On the back plate 'ELLICOTT Royal Exchange London 9920'; the signature repeated on the dial below the figure XII.

Case: Open face silver case with the London hallmark for 1820 and the maker's mark W.R. The glazed bezel and back hinged to the middle with gold joints, the fixed dome with hole for winding. No case springs. A dumpy pendant and heavy ring bow. The back worn through. Diam. 55·7 mm, h. over glass 24·2 mm.

Dial and hands: Flat enamel dial, slightly cracked, with subsidiary seconds, signed in the upper half.

Gold minute and hour hands, steel seconds hand with a gold boss.

Movement

Ebauche marks C & N, 13°.

Dial plate diam. 49·1 mm; front plate diam. 47·3 mm; back plate diam. 44·0 mm; frame h. 8·4 mm.

Frame: Similar to cat. no. 85, but without a dust ring or cover.

Fusee: Similar to cat. no. 85, note the return spring for the setting-up-pawl in place on the barrel bridge, and also the turned oil retention rings around the third and fusee arbor bearings on the backplate, the other plain bearings similarly turned.

Going train: Similar to cat. no. 85.

Jewelling: Both fourth arbor pivots run in pierced jewels. The pivots of the escape pinion arbor and balance staff run in pierced jewels with endstones. Diamond endstone set in a blued steel ring on the balance cock.

Escapement: Earnshaw type of detent escapement with gilded brass escape wheel, sunk out on the upper side to leave only the teeth standing proud of the rim. The teeth occupying about half a pitch, with backs slightly rounded. The thick steel impulse roller polished all over and with radial impulse jewel.

The jewelled polished discharge roller without a flat for adjustment.

The very well-made detent held by a single screw in a slot in the back plate. The passing spring of steel pinned to a block (c.f. Thomas Earnshaw cat. no. 63), half-round ruby locking stone of 0·45 mm diam. The detent planted with the foot well inside a tangent to the tip circle of the escape wheel at the locked tooth. The detent horn is therefore bent towards the passing spring which is thus held well clear of the detent.

Balance: Bimetallic three-armed balance, the brass segment weights held by steel plates and screws.

Balance spring: Blued steel helical spring of $5\frac{1}{2}$ turns, and with terminal curves, free sprung to a polished steel stud on the balance cock. A brass collet on the balance staff. Diam. of rim 19·2 mm, h. 2·2 mm.

Going-train counts:
Great wheel (fusee) 60 teeth, worn
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection. purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1596).

85 ELLICOTT

1823–4

CHRONOMETER *Plate 56c–d*

Signature: On back plate 'Ellicott LONDON L0078'.
On the balance cock 'Chronometer Escapement applied by Brockbanks & Atkins 1834'.

Dial and hands: Flat enamel dial, damaged, with Roman hour numerals and subsidiary seconds dial, signed below the figure XII 'ELLICOTT Royal Exchange'.

Gold minute and hour hands, seconds hand missing.

Movement
Ebauche marks 16·6.

Dial plate diam. 46·0 mm; front plate diam. 43·9 mm; back plate diam. 39·0 mm; frame h. 6·6 mm.

Frame: Full plate with four turned pillars, the back plate retained by pins, detachable barrel bridge. A dust ring retained by two dog screws at the edge of the back plate, one missing. The dial plate carrying the movement hinge fixed to the front plate by three short feet and pins, scratched on the front 'Wident' and faintly 'Ellicott'. The case catch and spring screwed to the front plate under the dial. The frame dust ring and dial plate gilded.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel steel. The barrel arbor with an extended square at both ends, the blued steel setting-up ratchet wheel and click mounted on the barrel bridge. The barrel with a flange at the cover end. The setting-up click return spring and screw missing from the barrel bridge.

Going train: Brass wheels gilded, the steel pinions, pivots, arbors and undercuts polished.

Jewelling: The lower pivot of the fourth arbor in a pierced jewel. The pivots of the escape pinion arbor and balance staff in pierced jewels with endstones. Diamond endstone in a blued steel ring on the balance cock.

Escapement: The original escapement, replaced by Brockbanks and Atkins, was presumably either a cylinder or a duplex. The escapement now fitted is an Earnshaw type of detent escapement with brass escape wheel sunk out on the upper side to leave only the teeth standing proud of the rim. The wrecked dovetailed detent was set in a gilded brass cock with integral banking. Both the impulse and discharge rollers are jewelled, the former with its jewel leaning slightly forwards. Both are grained, being unpolished on any surface. The discharge roller has a flat for adjusting.

Balance: Bimetallic two-armed balance, the steel parts blued, with steel quarter and brass compensation screws, two of the quarter screws in the wrong positions. Diam. of rim 18·0 mm, h. 1·58 mm.

Balance spring: Blued steel spiral spring of $7\frac{3}{4}$ open turns, free sprung to an overhanging polished steel stud screwed to the back plate.

Balance cock: The original balance cock probably fitted better against the end of the barrel bridge, and must have carried an index with tail passing over the back plate. The engraved indications for slow and fast remain.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 6 arms
Fourth pinion 8 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1596).

86 ANTHONY MESURE

c. 1820[1]

CHRONOMETER *Plate 56e–f*

Signature: On the back plate 'Anth^{y} Mesure London No 1043'.

Case: Later open face silver case with a fixed dome, the glazed bezel and back both hinged to the middle. The back opening by a push-piece and case catch at the pendant and a single fly spring acting on the back joint. Floral engraved decoration round the winding hole in the dome. The middle and back decorated with engine turning, and a shield in the centre of the back. London hallmark possibly for 1861 and casemaker's mark J.K., and the number 1043 repeated inside the dome and back, and the watch number and hallmark also on the bow and pendant. Diam. 59·0 mm, overall h. 24·8 mm.

Dial and hands: Flat enamel dial inscribed CHRONOMETER[2] in top half and with subsidiary seconds, attached to the dial plate by three feet and pins.

Blued steel minute and hour hands, the seconds hand missing.

Movement

Dial plate diam. 53·4 mm; front plate diam. 51·4 mm; back plate diam 47·7 mm; frame h. 8·4 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins. The balance potance foot set towards the centre of the back plate instead of towards the edge beside the barrel. A dust ring once retained by two dog screws on the edge of the back plate, now missing. The dial plate attached to the front plate by three feet and pins, and carrying the new movement hinge partly filed away to fit into the replacement case. The dial plate scratched '3 and 5 William Goswell London cased July 1861'. The new case catch and spring fitted on the front plate under the dial. The brass parts gilded. One empty rectangular hole of unknown purpose on the edge of the front plate near the case catch.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass. Setting-up-work on the front plate under the dial, in a shallow recess, the barrel arbor with an extended square on that end only. The barrel flanged on the cover end. The maintaining power detent does not belong to this watch and has been bent and filed to fit.

Going train: Remarkably crudely made and badly finished, only the pinions and pivots polished. The brass wheels not gilded.

Jewelling: The pivots of the third, fourth and escapement in pierced jewels with screwed settings, those of the escapement with endstones. A diamond endstone in a wide white steel setting on the balance cock.

Escapement: The remains of a detent escapement of Earnshaw type. The wrecked brass escape wheel with rim and arms sunk below the level of the teeth. The detent foot only remaining, screwed to the underside of the back plate beside a banking piece carrying a banking screw, which is also screwed to the underside of the back plate. Solid steel impulse roller, the edge, bottom and large radial impulse notch once polished. The discharge jewel set in a wedge-shaped roller below the impulse roller.

Balance: Bimetallic two-armed balance, not original, with brass segment weights held with steel plates and screws from the top. Timing screws set in the rims at the ends of the arms. Diam. 21·0 mm, h. 2·0 mm.

Balance spring: Blued steel flat spiral spring of 10 turns, without overcoil or terminal curves, free sprung to a brass stud on the balance cock. Round brass collet on the balance staff.

Balance cock: Of unusual shape and set slightly inside the edge of the back plate. The upper surfaces decorated with engraving of acanthus leaf, dog tooth, a basket of flowers and other motifs.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 8 leaves, wheel 48 teeth, 5 arms
Fourth pinion 8 leaves, wheel 60 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 15,428 $\frac{4}{7}$

Motion work:
Cannon pinion 12 leaves, brass minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth
Minute wheel and pinion probably not original.

Notes

1. Baillie 1951 lists Anthony Mesure at 8 Craven Building, Drury Lane, London, in 1810 and at 420 Strand, 1814–23.
2. The cheap construction, poor finish and technical primitiveness of this watch suggest that it might well be a early example of an attempt to deceive or take advantage of the esteem merited by the title chronometer, which is marked on the dial.

Provenance: Ilbert Collection (reg. no. CAI-1729).

87 CHARLES YOUNG

c. 1820

MARINE CHRONOMETER *Plate 57a–e*

Signature: On the dial only '(No 503) CHARLES YOUNG'.[1]

Box: The movement protected by a brass drum fitting on the back of the dial plate and held by screws and a positioning peg. This drum fitting into a larger but similar drum, also held with screws through the side into the inner drum. The glazed bezel on a bayonet catch. On the bottom of the inside of the outer drum is fitted a massive shaped brass disc, to level the drum in the gimbal ring, and on the outside an escutcheon plate pivoted at the centre and with an offset key hole. The gimbal ring is pivoted on the turned ends of screws passing through opposite sides of the box, and is provided with a lock. A key scratched 'No. 503' fitting into a wooden quadrant piece in rear right-hand corner of box.

The miniature mahogany box is well made and finished in the style of an ordinary-size two-day marine chronometer box. There is a glazed panel in the top with a hinged lid and catch in front. The lock has a flush fitted brass escutcheon plate. There are no carrying handles. Inside the lid is a label with the printed inscription 'Charles Young Jerusalem Coffee House'. On the box bottom is a label with the printed inscription 'Science Museum Birmingham 51/54'.[2]

Box 97·0 mm square × h. 93·0 mm

Dial and hands: Engraved brass dial, gilded, with a sunk silvered subsidiary seconds dial held with a screw. The back of the dial has three turned recesses to clear under dial work, and fits in a recess in the dial plate where it is held by two screws from the back.

Gold minute and hour spade hands, later blued steel seconds hand.

Movement

Ebauche marks 31 (or 3L) 33 on the dial side of the front plate.

Dial plate diam. 51·6 mm; front plate diam 46·2 mm; back plate diam. 44·4 mm; frame h. 7·9 mm.

Frame: Pocket watch-size full plate construction, with a detachable barrel bridge and four turned pillars, the back plate retained by pins. The front plate fits in a turned recess in the dial plate, the latter having three short turned feet passing into holes in the former and secured by pins. The centre of the dial plate has a shaped recess to clear the under dial work. The frame is not gilded, but finished with a scratchy polish.

Fusee: Fitted with the usual stop-work and maintaining power, the maintaining ratchet wheel steel, its detent and return spring combined and screwed to the edge of a brass block screwed and pinned to the inside of the front plate between barrel and fusee. The setting-up-work on the barrel bridge, the solid snailed arbor with an extended square on that end only.

Going train: Laid out and constructed as for a pocket chronometer, the pinions and arbors including the undercuts, polished. The train is unusual with a centre pinion of thirteen leaves and a fourth pinion of nine leaves.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A ruby endstone in the balance cock set in a polished steel ring.

Escapement: Spring detent escapement of Arnold type, the replacement brass escape wheel crudely made and not crossed out. Both rollers jewelled in the usual way and with polished edges, the impulse roller with two adjusting flats. The detent has a gold passing spring held by a rivet, the locking stone is set in a rectangular hole and held by a brass wedge. The stone projects on both sides of the detent, the upper end banking against a polished steel plate set in a sink in the back plate and with a pivot friction tight in a hole. It has two small holes for a tool to adjust the depth of locking.

Balance: Bimetallic three-armed balance, the steel parts blued, secured to a brass collet on the staff by three polished screws. Each bimetallic rim section is fitted with two brass segment weights each held in place by a brass plate and two screws and by a brass screw on the inside. The outside of the free end of each rim section is marked with fine inclined graduations to assist in adjustment of the compensation by the segment weight near the end of each rim. Diam. of rim 23·0 mm, h. 2·56 mm.

Balance spring: Blued steel spiral spring of 8½ turns pinned to a round split collet under the balance and to a small block screwed to a resilient spring on the back plate. This device is intended to eliminate the side pressures set up during the motion of a flat spring with rigid stud and partly obviates the need for a terminal curve.

Going-train counts:

Great wheel (fusee) 66 teeth, 6 turns of groove
Centre pinion 13 leaves, wheel 75 teeth, solid no crossings
Third pinion 10 leaves, wheel 72 teeth, 6 arms
Fourth pinion 9 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, sunk out but no crossings

Motion work:

Cannon pinion 13 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 52 teeth

Provenance: Ilbert Collection; purchased from Malcolm Gardner by Ilbert in 1933 (reg. no. CAI-1945). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Exhibited: British Watches and Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954; Pendulum to Atom under the auspices of The Worshipful Company of Clockmakers at Goldsmiths Hall, London, October 1958.

Notes

1. Baillie 1951 records a Charles Young in London, *c.* 1820; a marine chronometer by him is in the National Maritime Museum, Greenwich. In Britten 1982 'Charles Young 1805–17, London; duplex watch centre seconds, free balance spring, studs screwed to plate, *c.* 1805; marine chronom. Greenwich Museum, *c.* 1815; pocket chronometer, *c* 1817'.

2. Loose in the bottom of the box is a bill made out to 'His Grace the Duke of Norfolk, London, June 6th 1804', for '3/6', for repairing a timepiece, from 'Geo. Yonge, Watch and Clock Maker No 131 near Exeter Change, Strand', receipted on the 21 or 28 December, although the date has been altered.

88 BARWISE AND SONS

1822

CHRONOMETER *Plate 58a–b*

Signature: 'Barwise St. Martins Lane LONDON 5414'.

Case: 18-carat gold consular case open face with the London hallmark for 1822 and maker's marks W.M. and M. elsewhere. The dome fixed, the middle and back engine-turned. The fluted pendant somewhat resembles a Thomas Prest keyless, but is solid and with a push-piece to operate the lock spring and open the back. Pendant and bow marked 18. One of the two fly springs broken. Diam. 53·2 mm, h. 22·0 mm.

Dial and hands: Flat enamel dial with bold Roman hour numerals and sunk subsidiary seconds at 6 o'clock, signed in the upper half, 'BARWISE ST. MARTINS LANE LONDON. 5414'.

Gold minute and hour hands, the minute hand a replacement, steel seconds hand.

Movement

Ebauche marks: 20, 10

Dial plate diam. 47·5 mm; front plate diam. 44·6 mm; back plate diam. 41·8 mm; frame h. 7·3 mm.

Frame: Full plate with four turned pillars, the back plate secured by blued steel screws and brass washers. Detachable barrel bridge. The movement hinge carried on the dial plate, the case catch and spring on the front plate under the dial. Possibly once had a dust cover, only the screw holes for the retaining pillars remain. The dust pipe also removed.

Fusee: Keywind fusee, with stop-work, and maintaining power with a steel ratchet wheel. The return spring for the maintaining detent a short piece of wire set in a screw in the back plate. The setting-up-work on the barrel bridge, the setting-up ratchet wheel with fine teeth, the click controlled by a spring. Another square at the opposite end of the barrel arbor to assist in setting up or for an alternative position for the setting-up ratchet.

Going train: Usual construction, the brass wheels gilded.

Jewelling: The pivots of the third and fourth arbors in pierced jewels, those of the escapement in pierced jewels with endstones. The endstone in the balance cock is a ruby. The discharge roller jewelled.

Escapement: Earnshaw type of detent escapement, the brass escape wheel with 3 arms, not gilded. The dovetailed detent missing, its gilded brass support block with blued steel banking, adjusting and fixing screws. Polished steel impulse roller, the edge, the unusually small notch and the bottom polished. The impulse face on a radial from the centre.

Balance: Bimetallic two-armed balance of Earnshaw type with segment brass compensation weights secured by radial screws on the inside. The steel parts of the bimetallic rims blued. Steel timing screws set in the rims next to the ends of the crossbar. Diam. of rim 16·8 mm, h. 1·65 mm.

Balance spring: Blued steel helical spring, of $5\frac{1}{2}$ turns and with terminal curves, free sprung to an adjustable overhanging stud fixed to the back plate at the end of the barrel bridge.

Balance cock: Engraved acanthus motif decoration on the upper surfaces.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

The minute and hour wheels gilded, the minute pinion polished steel.

Provenance: Ilbert Collection; purchased by Ilbert in 1930 (reg. no. CAI-1847).

89 BREGUET ET FILS

c. 1824 (see note)

CHRONOMETER *Plates 58c–e, 59a*

Signature: On both the cuvette and the back plate 'Breguet et fils HOR^{GERS} DE LA MARINE ROYALE No 4216'. On the dial 'BREGUET ET FILS.'

Case: Open face silver case, the bezel, middle and back decorated with engine turning, the joints gold, no fly springs or catch for the back, solid pendant. Inside the back the numbers 462, 4216 over B, the French quality control mark for 1821–38 and a casemaker's mark. The brass cuvette with bayonet fixing and a locking screw. Overall diam. 58·6 mm, h. 23·7 mm.

Dial and hands: Matt silvered brass dial with rim on underside, the engraving filled with black wax, retained by a single screw near the centre and opposite the figure IX. Subsidiary seconds dial below XII o'clock.

Blued steel hands.

Movement

Ebauche marks 4216 and 3/5

Front plate diam. 51·2 mm; back plate diam. 45·7 mm; frame h. 9·8 mm; front plate th. 3·0 mm.

Frame: Remarkably similar to English work of the period but with detailed differences, perhaps an imported ébauche.

Full plate construction with four turned pillars, the back plate secured by pins. Detachable barrel bridge. Moulded edge to the foot of the balance potance resembling the English practice. No dial plate, the movement secured in its case by three large and beautifully finished dog screws on the front plate and with a positioning peg. The front plate cracked from the edge towards the centre, breaking into the recess for the fourth arbor. Strengthening added at the edge by a gilded brass plate over the crack held by two screws and steady pins. The crack was apparently caused when a peg was forced into a hole, still visible, in the edge of the front plate, before the frame was gilded. A number of holes drilled in the plates to allow the going-train gearing to be checked. The numbers 4216 and 35 stamped on the front plate under the dial, the latter partly obscured under the head of one of the screws holding the repair plate over the crack.

Fusee: A special cock to take the screw hole for the dial fixing and barrel. Keywind fusee with English stop-work and Harrison's maintaining power with a steel ratchet wheel. The mainspring with a square hook at its outer end, the barrel arbor with an extended square at both ends, the setting-up-work under the dial. The barrel flanged at the cover end.

Going train: The crossing out of the wheels is of typical French style.

Jewelling: Only the pivots of the escapement run in pierced jewels, with endstones of English type. The detent locking and discharge roller are also jewelled, but not the impulse roller.

Escapement: Earnshaw type of spring detent escapement with brass escape wheel. The polished impulse plane of the steel impulse roller leaning towards a radial from the centre of the roller to the tip of the impulse plane. The bottom of this roller polished, the edge and top left grained. The discharge roller jewelled in the English way, in which the jewel is set in a hole drilled parallel with the axis of the balance staff and just breaking into the edge of the roller. The light well-made detent planted on a straight line from the balance centre through the tip of the locked escape tooth, and not on a tangent to the tooth tip circumference of the escape wheel at the point of locking.

Balance: Bimetallic two-armed balance made in Earnshaw style with brass segment weights secured by steel screws on the inside and with brass screws set in from the outside, possibly for making small adjustments to the poising. Timing nuts at the ends of the crossbar on threaded studs set in the rims. The steel parts of the balance itself blued. Diam. of rim 25·5 mm, h. 3·5 mm.

Balance spring: Blued steel helical spring of 6½ turns, with terminal curves at each end, free sprung to a self-aligning stud held under a steel plate on the balance cock and to a brass collet. The spring thinned at its lower, collet, end so that the coils work appreciably more there.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 75 teeth, 5 arms, gilded
Third pinion 10 leaves, wheel 72 teeth, 5 arms, gilded
Fourth pinion 9 leaves, wheel 60 teeth, 5 arms, gilded
Escape wheel 6 leaves, wheel 15 teeth, 3 arms, gilded
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from the firm of Breguet in 1930. According to the reissue Certificate dated 24 April 1930, No. 2765, the watch was originally sold to a M. Perrochel on 21 August 1824 for the sum of 1,500 francs (reg. no. CAI-1849).

Note: The mainspring has been replaced, the outer end of probably the original spring being attached to the new one with a single rivet. The new one is marked *Tidélia 11/12/20*. The gilding on the edge of the barrel is undamaged, suggesting that the original outer backing has been reused for the new spring.

Exhibited: Musée International d'Horlogerie, La Chaux-de-Fonds, May–September 1976, see exhibition catalogue, p. 40.

90 W & J BAIRD

c. 1825

CHRONOMETER MOVEMENT *Plate 59b–e*

Signature: On the back plate 'W & J Baird LONDON No. 1734'. On the dust cover 'W & J Baird: LONDON'.[1]

Dial and hands: Flat enamel dial fixed to the dial plate by three short feet and pins. Roman hour numerals, Arabic seconds numerals, the divisions for both minutes and seconds a series of dots between scribed circles.

Gold spade hour and minute hands, blued steel seconds hand.

Movement
Dial plate diam. 47·3 mm; front plate diam. 44·4 mm; back plate diam. 42·0 mm; frame h. 6·9 mm.

Frame: Full plate construction without a barrel bridge, four turned pillars, the back plate retained by pins. The movement hinge attached to the dial plate, the case catch and spring on the dial side of the front plate. The well-made dust cover with a hole for the balance cock table, attached to two polished steel pillars on the back plate by a semicircular clip, and having a 'fleur-de-lis' punch mark on the inside. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass, the block for the stop-piece of simple square shape with a central slot for the stop-piece itself. The setting-up-work fitted in a shallow recess on the dial side of the front plate, the barrel arbor with an extended square on that end only. The barrel with a flange at the cover end, and with what is probably the original mainspring signed 'G. Ansell and Son'.[2]

Going train: Coventional layout and construction but very well made and finished, the pinions with unusually narrow leaves and long addenda similar to the wheel teeth, as usual in France and Switzerland at this time. The train count with very unusual numbers (see below). The cannon pinion held with a pin on the extended centre arbor.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A diamond endstone set in a polished steel ring is fitted in a recess in the balance cock.

Escapement: A development of Earnshaw's spring detent escapement. The well-made brass escape wheel having short fine teeth, the arms sunk below the level of the rims and teeth in two steps. The steel impulse roller with the edge and notch polished, and with a segment-shaped poising hole opposite the notch. The impulse face is set on a radial. The steel discharge roller has two flats for adjusting, the sides of the discharge jewel and its slot are both parallel.

The detent is held with a screw and steady pin on the side of a gilded brass block, itself secured by a single screw in a dovetailed slot in the back plate. Banking for the detent is provided against the head of a polished steel screw set in the block, acting on an extension of the locking-stone pipe. The passing spring appears to be of brass and is held by a single rivet to the detent. The ruby locking stone is of trapezium shape in horizontal section. (See also James McCabe No. 10254, cat. no. 98, for a similar detent fixing block and banking.)

Balance: Bimetallic two-armed balance, recessed on the underside, the two cuts in the bimetallic rims made midway between the arms. A single gold compensation screw at the end of each portion of rim, brass timing screws at the ends of the arms. Diam. of rim 20·2 mm, h. 2·1 mm.

Balance spring: Spiral open-coiled, undersprung, blued steel spring of 8 turns without an overcoil or terminal curve, free sprung to a small brass stud screwed to the back plate, and a round brass collet.

Amplitude limiting device: A small brass peg pointing outwards from the outermost coil of the balance spring moves into the path of a pin pointing downwards from one arm of the balance. This pin moves past a brass piece screwed to the back plate, and if the amplitude of the balance increases beyond a certain value, it carries the small peg on the balance spring until the latter hits that on the back plate. This prevents the balance from turning further.

Going-train counts:
Great wheel (fusee) 65 teeth
Centre pinion 13 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 72 teeth, 6 arms
Fourth pinion 9 leaves, 68 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: $17{,}485\frac{5}{7}$

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1586).

Notes

1. Baillie 1951 lists W. and J. Baird 1815–25.
2. See no. 2, cat. no. 74, for details of George Ansell.

91 BARWISE

c. 1825

MARINE CHRONOMETER *Plate 60a–b*

Signature: On the back plate 'Barwise No. 4307 London' and the Admiralty arrow. On the dial 'Barwise London 4307 ONE DAY', and the Admiralty arrow in the subsidiary seconds dial.[1]

Box: The movement contained in a brass bowl, numbered 4307, and gimballed in a mahogany box. The brass bowl has a spring-loaded dust-excluding plate of large diameter in the base which normally covers the winding hole, the threaded bezel has a flat glass and there is a lock for the gimbal ring and bowl. The box has carrying handles, a lock with brass escutcheon, a brass cross let into the lid and an ivory inset disc in the front of the lid engraved 'BARWISE 4307 ONE DAY' and the Admiralty arrow. In the main lid is a label 'Issued from Royal Observatory Greenwich 191. 21st Dec 1917.' The top is glazed under a hinged lid and there are four rubber feet screwed to the bottom over a fabric covering. On the join where the top meets the bottom when the box is closed, a strip of green fabric to exclude dust is glued to the top edge of the bottom. A winding key is in a corner piece in the box. Box 197 mm square, h. 200 mm excl. feet.

Dial and hands: Silvered engraved brass dial, the engraving filled with black wax. There is no indication of reserve of going. The dial plate is recessed to take the dial flush with the edge where it is held by three blued countersunk screws.

Blued steel spade hands. Steel seconds hand with a long tail.

Movement

Dial plate diam. 121·7 mm; front plate diam. 105·7 mm; back plate diam. 105·3 mm; frame h. 29·4 mm.

Frame: Constructed like a large full plate watch, with four baluster turned pillars, the back plate retained by pins, without a detachable barrel bridge. The dial plate secured to the front plate by three short feet and pins, and cut away for the motion work, third and fourth arbor bearing bridge and the setting-up-work. It also has three holes for the feet of an enamel dial and grooves for the fixing pins. The balance potance has a moulded edge to the foot, and the balance cock is secured by two small screws. The cock is scratched 'sa 12 4307' with an arrow. There are three equally-spaced tapped holes in the edge of the front plate, for an alternative method of fixing the movement into its case.

Fusee: Has a wide groove of only $4\frac{1}{2}$ turns, a remarkably coarse pitch, with the usual stop-work and maintaining power, the wheel of brass. The stop-piece return spring blued and the maintaining detent and return spring are both polished. The setting-up-work is fitted on the dial side of the front plate, the barrel arbor with an extended square at both ends. A brass dust-excluding cup is held by a screw on the winding arbor. There are two winding clicks in the fusee.

On the underside of the flanged barrel is faintly scratched '4307 Dent' and on the mainspring 'B. P. R. Smith Feb^{y} 1866'. The mainspring is hooked by hook and eye to both the solid, unsnailed barrel arbor and the barrel wall. A rectangular hole in the barrel wall for a solid hooking has been carefully fixed.

Going train: A well-made and finished train.

Jewelling: The lower pivot of the fourth arbor in a pierced jewel, those of the escapement in pierced jewels with endstones. A small diamond endstone in a deep polished steel setting in the balance cock. The jewelling is of the usual nineteenth-century English type with screwed settings.

Escapement: A development of Earnshaw's spring detent escapement with a brass escape wheel of modern pattern mounted on a tapered brass collet. The steel impulse roller not jewelled, the slightly convex impulse face polished, and leaning away from a radial to the tip. The discharge roller has an adjusting flat and is jewelled with a short piece of ruby. The dovetailed detent is planted on a tangent to the locked escape wheel tooth in a brass block screwed and steady pinned to the back plate and set well in from the edge. The block has an extended overhanging portion with a slotted hole at the end for the detent banking screw. There are separate clamping and banking screws for the detent foot, the latter having an eccentric peg in the end of what would normally be the threaded portion. In this instance it is smooth and friction tight in its hole. The gold passing spring is held by two rivets and the locking stone, a wedge-shaped piece of ruby, is dovetailed into its slot.

Balance: Later bimetallic two-armed balance with brass compensation screws and quarter nuts, fixed by two screws on what is probably the original brass collet on the balance staff. The collet now overlaps the crossbar. There is room under the balance cock for a balance of considerably larger diameter. Diam. of rim 38·4 mm, h. 4·7 mm.

Balance spring: Blued steel helical balance spring of $10\frac{1}{4}$ turns free sprung. The upper end pinned to a brass stud screwed to the balance cock, the lower end pinned to a split collet of rectangular shape. Terminal curves at both ends of spring.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:

Cannon pinion 12 leaves, the squared end flush with end of the centre arbor, minute pinion 14 leaves

Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; in his inventory notebook Ilbert states that he acquired this chronometer in 1930 from the Observatory, Greenwich, and that it had been used as an Admiralty chronometer since 1855, its previous owner unknown. Date of manufacture is stated to be about 1825. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1927).

Note

1. Baillie 1951 lists a John Barwise, 'London; 1790 d 1842 Chairman of BRITISH WATCH Co. Watch and pocket chron. G.M. cyl. watch S.M.S.K., Regulator St. James's Palace. Watch Den. coll.'

92 BREGUET ET FILS

1829

MARINE CHRONOMETER *Plates 60c–f, 61a–b*

Signature: On the dial 'Breguet et fils No 4324'.

Box: The movement contained in a brass bowl directly pivoted in the gimbal ring, and secured by two screws in the edge of the bowl. There is a bezel fitting friction tight on the dial plate and also secured by two screws in the side, glazed with a flat bevel-edged glass drilled for winding through the dial.

The gimbal ring is pivoted in a mahogany box, and fitted with a locking device in the bottom of the box operated by a lever at the side of the gimbal ring. Turning the lever clockwise causes a brass frame pivoted in the sides of the box to rise against a spring and press against the bottom of the drum. The box is fitted with handles, a lock, and a glazed aperture in the top covered by a hinged lid. There are also spring-loaded wood screws in the sides of the box, to secure this to a wooden surface (c.f. Breguet et Fils No. 2741, cat. no. 130). Base 250 mm square, h. 228 mm.

Dial and hands: Flat engraved and silvered brass dial held by a single screw near the centre in a shallow recess in the dial plate so that the dial stands proud. A large bush is fitted in the hole for winding, to protect the dial from damage when the key is inserted.

Blued steel hands for the small time of day and seconds dials and for the up-and-down sector.

Movement

Punched on the inside of the front plate 4524.

Dial plate diameter 139 mm; dial plate overall th. 22·2 mm; front plate diam. 126·5 mm; back plate diam. 122·3 mm; frame h. 53·6 mm.

Frame: Remarkably similar in construction and layout to the English eight-day chronometer calibre with cut-away back plate and a platform for the escapement mounted on the front plate (c.f. Barrauds No. 982, cat. no. 82). A type of half plate construction with three straight cylindrical pillars, held by recessed steel screws in the front plate, steel screws and polished washers on the back plate. The platform on which the escapement is mounted is secured by steel screws to three short brass pillars held by screws recessed in the front plate. The cast dial ring has a knurled flange on the outer edge, the front plate fits into it from the front and is secured by three screws passing through the plate into cast lugs on the dial ring. The brass parts are finished with radiating patterns applied with Water-of-Ayr or similar stone. There are various holes to view the gearing.

Fusee: Reversed fusee with Continental stop-work and Harrison's maintaining power, the ratchet wheel steel, the detent returned by a tapered wire fitted in a screw in the back plate. The setting-up-work mounted on the back plate. The well-made tapered unblued mainspring signed 'Vincent Avril 1826 76° 4325', scratched in the surface of the outside of the spring. It is hooked by hook and eye to the barrel and to the unsnailed brass boss on the arbor. There is a bride for the outer coil of the spring near the hooking.

Going train: The offset centre and third arbors carried between the plates, the fourth arbor between the front plate and a cock under the escapement platform with a large steel endplate. The wheels are held each with three screws on a brass collet on the arbor. The steel pinions and arbors are well finished and polished. The tooth form is remarkable in that the bottom of both wheel teeth and pinion leaves are rounded, from the great wheel to the fourth pinion inclusive. The centre and third wheels, and the third and fourth pinions appear to be the same pitch. The great wheel and centre pinion teeth have a finer pitch.

Jewelling: Only the balance staff pivot in the balance cock and the escape wheel pivot in its cock run in pierced jewels, both with diamond endstones. The other escapement pivots run in detachable brass bushes with steel endstone plates.

Escapement: Mounted on a separate detachable platform of lenticular shape with a fourth wheel lock operated by removing one of the fixing screws. There is not the usual separate number on the platform. The escapement of Earnshaw type has a brass escape wheel sunk out leaving the rim and teeth the full height, and is held with two screws on a brass collet on its arbor. The steel impulse roller is jewelled, the jewel leaning towards a radial to the tip. There are large passing and counterpoising holes. The escape wheel teeth show no signs of cutting or wear. The discharge roller, with two adjusting notches, is fitted above the impulse roller, towards the balance. It is jewelled and polished, the jewel being rounded on the passing side. The detent is attached by the spring portion under a piece of brass strip on a detachable bracket. Banking is by an eccentric brass plate held under a screw on an overhanging part of the detent fixing bracket. The locking stone is made from a cylindrical piece of pink ruby with two flats ground on the acting part. The passing spring appears to be brass, and is held under a screw on an integral bracket standing up from the detent. The end of the detent horn has an upstanding piece for the free end of the passing spring to rest against.

Balance: Bimetallic two-armed balance, the steel parts blued, the non-ferrous part a whitish metal tarnished yellow grey. Large brass quarter nuts are fitted on studs screwed into the rim, each against a flange. The free ends of the rim drilled with a series of tapped holes very close together, each rim section has a small gold screw to go in any one of these holes to alter the amount of compensation. The balance is held by two screws on a brass collet on the staff. Diam. of rim 34·8 mm, h. 3·30 mm.

Balance spring: Grey steel helical spring of $8\frac{5}{8}$ turns, without terminal curves, clamped concentrically at the full diameter of the spring to both collet and stud. The stud is clamped under a steel strip on a brass stand with three levelling screws. The collet is clamped by a transverse screw and has two poising screws in the tail. The central coils of the spring are thinned in relation to the outer ones so that the spring breathes more at the centre than the ends.

Going-train counts:
Great wheel (fusee) 144 teeth, $16\frac{3}{4}$ turns of groove
Centre pinion 12 leaves, wheel 120 teeth, 5 arms
Third pinion 15 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 80 teeth, 5 arms
Escape pinion 12 leaves, wheel 18 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 12 leaves
Hour wheel 48 teeth, minute wheel 42 teeth.

Provenance: Ilbert Collection; Ilbert in his inventory notebook records the acquisition of this chronometer from the firm of Breguet in Paris in 1932. According to the certificate no. 2792 issued in 1932, this chronometer was supplied to Ducom on 22 April 1829, for the price of 1800 francs. Presented by Mr Gilbert Edgar C.B.E. in 1958. (reg. no. CAI-1935).

Bibliography: L. J. Gay Lussac and Arago, *Chronomètres de Breguet*, 1819.

93 PARKINSON
c. 1830

CHRONOMETER MOVEMENT *Plate 61c–f*

Signature: On the barrel bridge 'PARKINSON London 574'.

Dial and hands: Flat enamel dial held by two rectangular feet and screws through the edge of the dial ring.

Gold hour hand, the minute and seconds hands later replacements.

Movement
Dial plate (ring) diam. 51·2 mm; front plate diam. 51·2 mm; back plate diam. 42·4 mm; frame h. 8·0 mm.

Frame: Full plate construction, the dial plate in the form of a ring held with three screws under the dial, thus leaving room for the repeating and motion work. Remainder of the frame conventional with four pillars and pins, the brass parts gilded, detachable barrel bridge.

Fusee: Keywind fusee fitted with stop-work and Harrison's maintaining power with a steel ratchet wheel.

Going train: Conventional; the brass wheels gilded.

Jewelling: Third, fourth and escapement pivots in jewels, the escapement with endstones. The discharge roller and detent with the usual jewels.

Escapement: Made on Earnshaw's plan but with the detent lodged in a slot in the plate like an Arnold detent. The discharge roller placed between the impulse roller and the balance collet. The impulse roller with a polished radial flat to receive impulse.

Balance: Earnshaw-type bimetallic balance with segment weights, timing screws at the ends of the arms each with a small additional gold screw beside it. Diam. 19·8 mm, h. 2·57 mm.

Balance spring: Blued steel helical spring of $8\frac{1}{2}$ turns, with terminal curves to a steel rectangular collet and a polished steel stud.

Repeating work: Stogden-type half-quarter repeating, operated by rack and pinion when the pendant is depressed.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 14 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Repeating-train counts:
First wheel 64 teeth
Second wheel 48 teeth, pinion 8
Third wheel 44 teeth, pinion 8
Fourth wheel 40 teeth, pinion 8
Fifth wheel 32 teeth, pinion 8
Final pinion 8 leaves

Provenance: Ilbert Collection, purchased by Ilbert in 1930 (reg. no. CAI-1740).

94 W. B. CLARKE
1837

CHRONOMETER *Plate 62a–b*

Signature: 'W. B. Clarke London'.

Case: Open face silver case with the London hallmark for 1837 and the maker's mark C.H. Pendant maker's mark W.O.(?) in a cameo, also hallmark for London 1837 on the pendant. Diam. 56·0 mm, h. 23·0 mm.

Dial and hands: Flat enamel dial of pale yellow-brown colour. Roman hour numerals, subsidiary seconds at 6 o'clock.

Brass minute and hour hands, steel seconds hand.

Movement
Ebauche marks 22, 12.
Dial plate diam. 50·6 mm; front plate diam. 48·0 mm; back plate diam. 44·6 mm; frame h. 8·0 mm.

Frame: Full plate with four turned pillars, the back plate retained by blued steel screws. Detachable barrel bridge. The dial plate carrying the dial and movement hinge attached to the frame with three short pillars and pins. The case catch and spring mounted on the front plate under the dial. No dust cover. The frame and dial plate gilded. The setting-up ratchet with a spring.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel of steel. The polished steel setting-up-work mounted on the barrel bridge. The maintaining detent and return spring of polished steel. The barrel arbor squared at both ends.

Going train: Not unusual except the great wheel has fifty-nine teeth. The brass wheels gilded.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, the escapement with endstones. A diamond endstone set in a blued steel ring on the balance cock.

Escapement: Earnshaw style of spring detent escapement, the gilded brass four-armed escape wheel with teeth of Earnshaw pattern, the pivots and those of the balance staff of the form which he used. The impulse roller with radial impulse pallet, the usual jewelled discharge roller. The detent with solid foot mounted on a brass block dovetailed in a slot in the back plate and held with two screws. The single screw to hold the detent also passing down from the back plate. The gold passing spring held with a screw. The brass banking screw for the detent set in a gilded brass block, the foot pinned and screwed well inside the edge of the back plate.

Balance: Bimetallic two-armed balance with brass segment compensation weights held with polished steel plates and screws. Steel timing screws in the rims at the ends of the arms.

Balance spring: Blued steel helical spring of seven complete turns, and with terminal curves, free sprung to a polished steel stud on the balance cock. Brass collet on the balance staff. Diam. of rim 18·2 mm, h. 1·73 mm.

Balance cock: Plain, without decoration.

Going-train counts:
Great wheel (fusee) 59 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Webster in 1929 (reg. no. CAI-1725).

95 BARWISE AND SONS

c. 1820

CHRONOMETER *Plate 62c–d*

Signature: 'Barwise and Son's London No 7350'.

Case: Later 18-carat gold consular case (probably recased by Barwise) with the London hallmark for 1837 and the maker's mark, W.W., surmounted by an axe, in the inner case, numbered inside the dome 7350. The back and bezel engine-turned. A small crest of a displayed eagle on a wreath in the centre of the back. Diam. 55·6 mm, h. 20·4 mm.

Dial and hands: Flat enamel dial with subsidiary seconds at 6 o'clock, signed 'Barwise's No 7350' in the upper half.

Gold minute and hour hands, blued steel seconds hand.

Movement

Ebauche marks ---^{8}.

Dial plate diam. 48·0 mm; front plate diam. 46·3 mm; back plate diam. 43·8 mm; frame h. 7·3 mm.

Frame: Full plate with four turned pillars, the back plate secured by pins. Detachable barrel bridge. The dial plate carrying the case hinge, the catch and spring under the dial on the front plate. The movement originally fixed in the case with a pin and two screws through the case edge. No dust cover. Both plates numbered 7350 on their inner surfaces.

Fusee: Keywind fusee, with stop-work and maintaining power, the maintaining ratchet wheel brass. Setting-up-work on the front plate under the dial, the barrel arbor squared at both ends.

Going train: The brass wheels gilded.

Jewelling: The fourth lower and escapement pivots in pierced jewels, those of the escapement with endstones. A diamond endstone in a blued steel ring on the balance cock.

Escapement: Earnshaw type of detent escapement with ungilded brass escape wheel of Earnshaw style. Steel impulse roller, not jewelled, the bottom surface polished. The radial impulse plane not polished.

The dovetailed detent with half-round locking 'stone' of steel, set in a brass block carrying the banking screw, apparently all later replacements. Originally a detent was fitted with its foot screwed to the underside of the back plate. The holes for the detent remain, and also a brass banking piece, no longer used.

Balance: Bimetallic balance of Earnshaw type with segment brass compensation weights secured by radial screws on the inside. Steel timing screws set in the rims at the ends of the crossbar. Diam. of rim 18·0 mm, h. 1·52 mm.

Balance spring: Blued steel spiral spring pinned to a polished steel stud on the back plate near the maintaining detent pivot hole, the brass collet rectangular with rounded ends.

Balance cock: Plain and without decoration. On the centre line of the overhanging portion balance cock is set a brass plug with a screw head, and carrying two pins, one on each side of the last turn of the balance spring. These pins can be turned so as to alter their effective separation and thus provide a facility for isochronal adjustment.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 10 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 6 arms
Third pinion 8 leaves, wheel 60 teeth, 6 arms
Fourth pinion 8 leaves, wheel 70 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, brass minute pinion 15 leaves
Hour wheel 45 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Ash in 1932 (reg. no. CAI-1846).

Note: Baillie 1951 gives Barwise and Sons, London, 1819–23.

96 ROBERT AND HENRY MOLYNEUX
1835–1842

CHRONOMETER MOVEMENT *Plate 62e–f*

Signature: On the back plate and barrel bridge, and on the dial 'R & H Molyneux 30 Southampton Row London Nº 3004' (see also W. E. Cribb cat. no. 102).

Dial and hands: Flat enamel dial with subsidiary seconds, attached to the dial plate by three feet and pins.
The hands missing.

Movement
Ebauche marks ?0 × 9, 3004. Most of the brass parts of the frame also marked 3004.
Dial plate diam. 47·4 mm; front plate diam. 45·8 mm; back plate diam. 42·8 mm; frame h. 7·3 mm.

Frame: Typical full plate construction with detachable barrel bridge, four turned pillars, the back plate retained by pins. The dial plate attached to the front plate by three feet and pins, and having once carried the movement hinge, now removed. The case catch and spring fitted on the dial side of the front plate. All the brass parts gilded, both these and the steel parts badly deteriorated as a result of exposure to the elements.

Fusee: Keywind fusee with the usual stop-work and maintaining power with a steel maintaining ratchet wheel. The setting-up-work fitted in a shallow recess on the dial side of the front plate, the barrel arbor with an extended square on both ends, the barrel flanged on the cover end.

Going train: The usual layout and construction, the brass wheels gilded, the steel pinions and arbors once well finished and polished, now rusted.

Jewelling: The fourth arbor lower pivot in a pierced jewel, those of the escape pinion arbor and balance staff in pierced jewels with endstones. A diamond endstone in a very rusty steel setting on the balance cock.

Escapement: Earnshaw type of spring detent escapement, the gilded brass escape wheel with the arms sunk below the level of the rim and teeth. The polished steel impulse roller with the impulse plane leaning towards a radial to the end furthest from the balance centre (see Stephenson and Farrow, cat. no. 68, for a similar example). The polished steel discharge roller jewelled in the usual way, and without an adjusting flat. Only the very rusty foot of the detent remaining screwed to the underside of the back plate.

Balance: Bimetallic two-armed balance with eight equally spaced brass screws. The steel parts of the rims were originally blued but are now rusty. Diam. of rim 18·0 mm, h. 2·35 mm.

Balance spring: Spiral steel spring of about 5½ turns without an overcoil or terminal curve, but pinned to a once polished steel resilient stud, and a round brass collet.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Jauncey in 1931 (reg. no. CAI-1608).

97 E. J. DENT
c. 1840

CHRONOMETER MOVEMENT *Plate 63a–b*

Signature: 'Dent London, No. 5727'. On the dial 'E. J. Dent, London 5727'.

Dial and hands: Flat enamel dial, Roman hour numerals, subsidiary seconds at 6 o'clock, signed below the XII 'E.J. DENT LONDON 5727'. Fixed directly to the front plate with three feet and pins. Repairs to dial between XI and XII.
The hands missing.

Movement
Ebauche marks 5727, 1$\overset{\cup}{\cap}$, GH.
Front plate diam. 45·5 mm; front plate h. 2·5 mm (recessed to 1·0 mm; back plate diam. 41·6 mm; frame h. 7·0 mm.

Frame: Half plate with three turned pillars, the back plate retained by blued steel screws. On the front plate a separate bridge for the bearings of the third, fourth, escape and balance arbor pivots. The hinge, case catch and spring removed. The frame gilded. On the underside of the cock the number 5727.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel of steel. Setting-up-work under the dial on the front plate.

Going train: The brass wheels gilded. Solid centre pinion with the cannon pinion friction tight on the extended arbor.

Jewelling: The fourth arbor lower pivot in a pierced jewel bearing, the pivots of the escape and balance arbors also in pierced jewel bearings with endstones. Diamond endstone on the balance cock. The escape wheel arbor upper jewelling missing.

Escapement: A development of the Earnshaw type of spring detent escapement. The brass escape wheel sunk out on the underside. The jewelled discharge roller mounted between the impulse roller and the balance. The impulse roller polished and set with a radial impulse jewel. The detent, originally mounted on the banking block beside the screw attaching this to the front plate, now missing.

Balance: Bimetallic two-armed brass and steel balance with steel quarter screws and brass compensation screws, the steel parts of the balance blued. There is a pin projecting inwards from the rim near the end of one arm to act as an amplitude limiting device with the resilient stud. Diam. of rim 15·4 mm, h. 1·77 mm.

Balance spring: Blued steel spiral balance spring of 8$\frac{1}{2}$ turns without overcoil or terminal curve, free sprung to a resilient stud with foot screwed to that of the balance cock. This enables the spring to breath evenly as if it had a correct terminal curve, but introduces poise errors.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 10 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Ash in 1932 (reg. no. CAI-1590).

98 JAMES McCABE

c. 1850

CHRONOMETER MOVEMENT *Plates 63c–f, 64a–b*

Signature: On the back plate 'Ja^{s} M^{c}Cabe Royal Exchange No 10254 LONDON'. On the enamel dial, in the upper half 'JA^{s} M^{c} CABE Royal Exchange LONDON, 10254'. On the dust cover 'Ja^{s} M^{c} Cabe Royal Exchange LONDON 10254'.

Dial and hands: Flat enamel dial with subsidiary seconds attached to the dial plate by three short feet and pins.

The hands missing.

Movement
Ebauche marks punched under the dial on the front plate, on the inside of the back plate and on the underside of the barrel bridge I.M.C. 10254. Also on the back plate under the setting-up ratchet 0 1·61.

Dial plate diam. 47·0 mm; front plate diam. 44·1 mm; back plate diam. 41·9 mm; frame h. 8·0 mm.

Frame: Full plate construction with detachable barrel bridge, four turned pillars, the back plate retained by pins. The dial plate secured to the front plate by three pillars and pins, and carrying the movement hinge. The case catch and spring mounted on the front plate under the dial. A well-fitting dust cover, cut away from the table of the balance cock, secured by a clip to two pillars on the back plate, marker's mark R.E. All brass parts gilded. On the balance cock four arrows and a cross superimposed.

Fusee: Keywind fusee fitted with continental stop-work, and the usual Harrison's maintaining power. The maintaining ratchet wheel brass. The setting-up-work fitted on the front plate under the dial, the barrel arbor with an extended square on that end only.

Going train: Well made and finished, the brass wheels gilded. The centre arbor and fourth lower pivot broken.

Jewelling: The fourth arbor lower pivot in a pierced jewel, the pivots of the escapement arbors in pierced jewels with endstones, a diamond endstone in a wide blued steel ring in the balance cock. All the jewelling in screwed settings.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with rim and arms below the level of the teeth. The impulse roller not jewelled but with a radial impulse face formed in a similar way to that of Earnshaw's (cf. cat. no. 63). All the surfaces polished except the top. The usual polished steel jewelled discharge roller without an adjusting flat. The detent screwed to the side of a gilded brass block with integral banking, dovetailed into the back plate and secured by a single screw. The detent planted well inside a tangent to the locked tooth so that both detent and passing spring are straight. The locking stone of half-round section, the spring part of the detent about 0·015 mm thick, and showing no sign of buckling, twisting or other strain. The gold passing spring secured by a screw.

Balance: Bimetallic two-armed balance, the rims cut through unusually far from the arms. Brass compensation and quarter screws. The balance riveted on a brass collet on the balance staff. Diam. 23·5 mm, h. 2·07 mm.

Balance spring: Blued steel spiral spring of 8 open coils, free sprung to a brass stud held in a slot under a polished steel plate on the balance cock. The brass stud with two pin holes. A round brass collet on the balance cock. Steel regulator.

Going-train counts:
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 6 arms
Fourth pinion 8 leaves, wheel 70 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, brass minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert in 1946 (reg. no. CAI-1607).

99 EDWARD THOMAS LOSEBY

(1817–1890)

c. 1850

MARINE CHRONOMETER *Plate 64c–f*

Signature: On the back plate 'Loseby London'. On the dial 'Loseby London 126'.[1]

Box: The movement contained in a brass bowl, the front bezel with a flat glass, gimballed in a brass-bound mahogany box. The box is fitted with the usual lock, carrying handles and a glazed panel in the top under a hinged lid. It is in mint condition but for the loss of the inset ivory disc in the front of the top. There is a numbered tipsy key. Box 161·5 mm square, h. 174 mm.

Dial and hands: Silvered flat engraved brass dial, the engraving filled with black wax, secured by two screws in a recess in the dial plate. The hour hand makes a revolution in 24 hours and the dial is engraved accordingly.

Gold minute and hour hands, blued steel seconds and up-and-down hands.

Movement

The frame parts numbered 126.

Dial plate diam. 91·4 mm; front plate diam. 76·5 mm; back plate diam. 76·7 mm; frame h. 22·0 mm.

Frame: Typical full plate construction with a detachable barrel bridge, four turned pillars, the back plate retained by blued steel screws. The dial plate a thick turned ring of brass, with the front plate fitting into a recess and held by three brass screws in the dial plate. The brass parts are hand spotted.

Fusee: Fitted with the usual stop-work and maintaining power. A large dust-excluding cap is fitted on the winding square, and the setting-up-work is on the barrel bridge. The well-made mainspring is solid hooked to the barrel wall, the arbor is unsnailed and made from the solid. The signature on the mainspring is almost illegible, it could be 'Cattin', 'Caffin' or 'Cotton'.

Going train: Well made and finished, the brass wheels polished flat on both sides, the pinions and arbors polished to the usual high standard of English chronometer work of the period.

Jewelling: The fourth pivot on the dial side, and those of the escapement, in pierced jewels, the escapement with endstones. A diamond endstone in a blued steel setting in the balance cock. The fourth jewel is protected by a pierced cover, recessed on the inside, held in the sink with the jewel setting by two screws. This is to prevent dirt from falling through the hole in the dial for the seconds arbor, and contaminating the oil in the jewel sink.

Escapement: A development of Earnshaw's spring detent escapement, and very well made throughout. The brass escape wheel with rim and arms recessed on the side towards the back plate. The steel impulse roller polished on the edge and hollow, grained on the top and bottom, and set with a radial jewel. The discharge roller polished on the edge and bottom, with an adjusting flat, and jewelled in the usual English way in a hole breaking into the edge. The detent straight and finished with a fine grain, with a gold passing spring held under a screw head. Banking is provided by the head of a brass screw set in a slotted hole in a bracket against the balance potance foot. The locking stone is triangular, and held with a brass wedge and shellac.

Balance: Bimetallic two-armed balance, the steel parts blued, secured by two screws on a brass collet on the staff. The free ends of the rim sections are shorter than usual and each carries a brass bracket held by the screw on which the quarter nut is fitted. Curved mercury-filled brass tubes are cemented into holes in the brass brackets. Each tube is held by its bulb and is curved towards the balance centre. Brass compensation weights and quarter nuts are also fitted. The purpose of the mercury tubes is to cause the rate of compensation to increase with rising temperature and decrease with falling temperature. This non-linearity of compensation can be adjusted to match the non-linear changes in elasticity of the carbon steel spring. A plain bimetallic balance and carbon steel spring has a losing rate at extremes of temperature if correct at a middle temperature. The diameters of the mercury bulbs, about 4·9 mm, do not differ by more than about 0·02 mm. Diam. of rim 29·4 mm, h. 3·6 mm.

Balance spring: Blued steel helical spring of 10 turns, with terminal curves. The brass collet has a split counterpoising tail, the brass stud is held with a screw in a slot on the balance cock. It has a screw in the side to adjust its distance from the balance centre.

Going-train counts:
Great wheel (fusee) 90 teeth, 8½ turns of groove
Centre pinion 14 leaves, wheel 90 teeth, 5 arms
Third pinion 12 leaves, wheel 80 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 10 leaves
Hour wheel 60 teeth, minute wheel 56 teeth.

Up-and-down work:
Pinion 8 leaves, wheel 90 teeth (identical with the centre wheel)

Provenance: Ilbert Collection; in his inventory notebook Ilbert states that he acquired this chronometer from Malcolm Gardner in 1942, and adds that it came from Loseby's executors (reg. no. CAI-1933).[2]

Exhibited: British Watches and Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954.

Notes

1. Edward Thomas Loseby died at Leicester in 1890. He submitted his first chronometer fitted with a balance embodying mercury in glass tubes to the Admiralty in 1843. More chronometers so fitted were tried at Greenwich in 1844 and 1845, and the Astronomer Royal, Airy, reported favourably on them. Between 1845 and 1853 Loseby obtained very good results in the trials at Geenwich, but finally became discouraged when he did not receive special financial reward for his work. He therefore retired to Leicester in 1853 where he worked as a high-class watch and clockmaker until his death

2. Malcolm Gardner in a letter to Gould dated 17 November 1948 records that this chronometer was with others in Loseby's effects at his death. Loseby had instructed his executors not to sell any of the chronometers. However, they gave them all to Robert Gardner on condition that he finish and return two to them free of charge. In 1941 Malcolm Gardner purchased two chronometers from the Grimson family, No. 126 being one of them.

Bibliography: Gould 1923, pp. 198–200; *An Account of Mr E. T. Loseby's Improvements in Chronometers, Watches and Clocks*, ed. J. J. Farmer, Coventry, 1852.

100 HENRY GOLAY

c. 1850

CHRONOMETER MOVEMENT *Plate 65a–d*

Signature: On the barrel bridge 'Hry Golay A Geneve No. 2766'.

Dial and hands: Unsigned flat enamel dial with subsidiary seconds secured directly to the front plate by two feet and pins; one pin broken. On the back of the dial in red 'Golay'.

Blued steel spade hands.

Movement

Ebauche marks 381 H. GOLAY GENEVE.

Front plate diam. 52·4 mm; back plate diam. 48·5 mm; frame h. 9·9 mm.

Frame: Owing an obvious debt to English full plate construction. Full plate with four turned pillars, the back plate retained by pins. Detachable barrel bridge. The movement was held in its case by one heavy positioning peg and a blued steel dog screw. The balance potance with moulded edge to the foot. The escape wheel pivoted between the back plate and a potance passing into a clearance hole in the front plate. A separate bridge on the front plate for the lower third and fourth bearings. The fusee lower bearing also in a separate bridge. The brass parts apparently electro-gilded.

Fusee: Keywind fusee with English stop-work and Harrison's maintaining power following English general design and layout. The maintaining ratchet wheel steel with very fine teeth. The barrel without flange, relieved at the lower end to miss the great wheel. Polished setting-up-work on the barrel bridge, the barrel arbor squared at that end only.

Going train: Similar to English work, the pinions turned with deep undercuts. The centre pinion so much weakened by this that the centre wheel has turned.

Jewelling: The pivots of the centre, third, fourth and escapement arbors in finely-made pierced jewels. Only the pivots of the balance staff with endstones. The diamond endstone in the balance cock loose under a steel plate and not soldered as in English work. All the train jewels *bombé* (i.e. convex on the surfaces towards the pivot shoulders) except those for the escape pinion arbor. The top escape jewel in a screwed setting as is the balance jewellery.

Escapement: A derivative of the Earnshaw detent escapement. The steel escape wheel with tooth form similar to that used by Thomas Earnshaw, polished, and recessed to the rim. The impulse and discharge rollers mounted at the lower end of the balance staff. The impulse roller hollow with polished edge, and jewelled, the impulse pallet leaning towards a radial from the roller centre to its tip. The steel discharge roller also jewelled and with two grooves for adjusting. The detent secured by a screw in a groove in a block screwed to the underside of the back plate, and having another screw to move the detent towards or away from the balance. The detent itself now made up of three separate pieces riveted together, the foot, the central spring, and the end with the locking stone, having been repaired. The locking stone set in a groove, the steel passing spring held by a screw. Banking for the detent provided against a gold screw set in another separate block screwed to the underside of the back plate. The detent foot set well inside a tangent to the locked tooth of the escape wheel.

Balance: Bimetallic two-armed balance of Earnshaw type with gilded brass segment compensation weights held by screws from the inside. The balance itself held by two screws to a large integral flange on the balance staff. Platinum timing screws on the rim near the end of the arm. Diam. of the rim 19·0 mm, h. 1·63 mm.

Balance spring: Blued steel helical spring of small diameter having 6 complete turns. At the lower end a very short terminal curve to a poised brass collet, at the top no terminal curve, the spring pinned to a steel stud on the balance staff. An index is provided on the balance cock for mean time adjustment. The middle coils not reduced in thickness, so that the spring breathes badly.

Hand setting: From the back via an arbor with squared end, pivoted in the frame between the barrel and the fusee. An extended square under the dial carries a wheel engaging with the minute wheel.

Going-train counts:
Great wheel (fusee) 66 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Wartski in 1932 (reg. no. CAI-1601).

101 E. J. DENT

1851

CHRONOMETER MOVEMENT *Plate 65e–f*

Signature: 'E. J. Dent, Watchmaker to the Queen LONDON N° 10215.

Dial and hands: Flat enamel dial damaged around the edge, Roman hour numerals, sunk subsidiary seconds at 6 o'clock, signed below the XII 'E. J. DENT LONDON 10215'. The dial fixed directly to the front plate with three feet and pins. The number 15 on the back.

Gold spade minute and hour hands, blued steel seconds hand, a replacement.

Movement

Ebauche marks 18, 0, 10215. 215 on the balance cock foot.

Front plate diam. 46·0 mm; front plate th. 2·75 mm; back plate diam. 41·4 mm; frame h. 6·80 mm.

Frame: Similar to cat. no. 97, the case catch spring still in place, but case catch missing.

Fusee: Similar to cat. no. 97.

Going train: Similar to cat. no. 97.

Jewelling: Both pivots of the fourth arbor in rubbed-in jewelled holes, otherwise similar to cat. no. 97.

Escapement: A development of the Earnshaw type of spring detent escapement. The brass escape wheel sunk out on the upper side, with nearly triangular-shaped teeth when viewed from above. The wheel mounted on a polished steel collet. The normal jewelled discharge roller below the impulse roller on the balance staff. The steel impulse roller polished all over and with a radial impulse jewel. The detent planted beside the polished steel banking piece with a screw at the end acting on the detent pipe. The detent itself with polished foot, gold passing spring held with a screw, and a half-round locking jewel 0·45 mm diameter.

Balance: Bimetallic two-armed balance, the steel blued, with steel quarter screws and brass compensation screws, the screws unusually large. Diam. of rim 15·4 mm, h. 1·78 mm.

Balance spring: Blued steel helical spring of 5 complete turns and with terminal curves. A brass poised collet with slot, a polished steel stud on the balance cock.

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, brass minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Cottell in 1933 (reg. no. CAI-1591).

Note: This watch appears on Dent's stock book in 1851 and was manufactured by Herrick.

Bibliography: Mercer 1977.

102 W. E. CRIBB
1857

CHRONOMETER *Plate 66a–b*

Signature: 'W. E. Cribb, 30, Southampton Row Russell Sq^e LONDON 3726'. (succeeded R. and H. Molyneux, see cat. no. 96). On dial W. E. CRIBB LONDON 3726.[1]

Case: Plain open face silver case with the London hallmark for 1857 and the maker's mark AT over L 3726. Pendant with TC in cameo and London mark for 1857. The bezel and back hinged to the middle, the dome fixed, no case springs. Diam. 55·7 mm, h. 22·6 mm.

Dial and hands: Flat enamel dial with red 12 fired into back of dial and sunk subsidiary seconds dial at 6 o'clock, fixed directly to the front plate by three feet and pins. Blued steel hands. Minute and seconds hands probably not original.

Movement
Ebauche marks 22, 10.
Front plate diam. 49·0 mm; front plate h. 2·8 mm; back plate diam. 44·7 mm; frame h. 9·0 mm.

Frame: Full plate with four turned pillars,[2] the back plate held by blued steel screws. Detachable barrel bridge. No dial plate or dust cover. The front plate sunk out under the dial, and carrying the hinge and the case catch and spring.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The fine blued steel setting-up pawl and ratchet mounted on the barrel bridge.

Going train: The usual layout and construction, the brass wheels gilded, the pinions and arbors well finished and polished.

Jewelling: The lower pivot of the fourth arbor in a pierced jewel. The pivots of the escapement in pierced jewels with endstones, in the balance cock a diamond endstone, set in a blued steel ring.

Escapement: Earnshaw type of detent escapement, the teeth of the brass escape wheel with a very pronounced undercut. The steel impulse roller not jewelled, only the edge and radial impulse face polished. Usual jewelled discharge roller. The detent broken, only the solid foot remaining screwed to the underside of the back plate beside the gilded brass banking piece and screw.

Balance: Bimetallic two-armed balance with gold compensation and quarter screws. Diam. of rim 18·2 mm, h. 1·77 mm.

Balance spring: Blued steel helical spring, 7 complete turns and with terminal curves pinned to a brass collet and a polished steel stud on the balance cock.

Balance cock: Plain, the foot not reaching to the edge of the back plate, the overhung portion particularly thick (1·6 mm).

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Ash in 1932 (reg. no. CAI-1727).

Notes

1. William Cribb, 58 Theobalds Road, 1816-22, 17 Southampton Row, 1829; a chronometer maker who succeeded Birchell and Appleton, formerly Molyneux, died 1876 (see Britten's *Old Clocks and Watches and their Makers*, 6th edn, London, 1932).

2. This watch is unusually late for full plate construction; note that the dial is fixed as in three-quarter plate work.

103 GEORGE E. MYLNE
1860

CHRONOMETER MOVEMENT *Plate 66c–d*

Signature: On the back plate 'George E. Mylne 2 Gt Percy S London $\frac{64}{4508}$'. On the dial 'G. E. MYLNE LONDON $\frac{64}{5408}$'.[1]

Dial and hands: Flat enamel dial with sunk subsidiary seconds, fixed to the front plate by three feet and pins.

Blued steel hands.

Movement
Ebauche marks A & G, 14, 2 and 64 over 5408.

Front plate diam. 42·4 mm; back plate diam. 38·1 mm; frame h. 7·4 mm.

Frame: Typical half plate construction, three turned pillars, the back plate retained by recessed steel screws. The movement without a case hinge or catch or any provision for either, and retained in its case by a peg and two small screws passing into the edge of the front plate. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up work in a shallow recess on the front plate under the dial, the barrel arbor squared on that end only. The barrel flanged on the cover end.

Going train: The centre pinion solid and carrying the cannon pinion on its extended arbor. The brass wheel burnished and not gilded. The steel pinions and arbors polished, and with polished undercuts.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones in screwed settings. A diamond endstone in a polished steel ring on the balance cock.

Escapement: A development of the Earnshaw spring detent escapement. The brass escape wheel with rim and arms sunk below the level of the teeth. The steel impulse roller polished all over and with a radial set jewel. The usual jewelled discharge roller. The detent a later replacement of very poor quality and finish, set with a half-round locking stone and a gold passing spring screwed on, and planted well inside a tangent to the locked escape wheel tooth. Detent banking provided against the end of a screw set in a polished steel bar integral with a semicircular ring concentric with the balance lower bearing, and secured in a recess by two marked screws.

Balance: Bimetallic two-armed balance with steel quarter screws, and platinum and gold compensation screws. Diam. 18·0 mm, h. 1·8 mm.

Balance spring: Blued steel helical spring of $6\frac{1}{2}$ turns, with terminal curves, free-sprung to a diamond-shaped polished steel stud on the balance cock. The steel collet polished, and slotted to give it some spring on the balance staff.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1609).

Note

1. Britten 1982 records (*Old Clocks and Watches and their Makers*, 6th edn, London, 1932) that this maker was at one time Honorary Secretary of the British Horological Institute, and that he died in 1868 aged 53.

104 CHARLES FRODSHAM
c. 1867

CHRONOMETER MOVEMENT *Plates 66e–f, 67a–c*

Signature: On the back plate 'Cha$^{\underline{s}}$ Frodsham 84 Strand LONDON AD Fmsz N° 03503'. On the dial 'CHA$^{\underline{S}}$ FRODSHAM No. 03503 AD F.m.s.z.'.

Case: No case but was open face.

Dial and hands: Flat enamel dial with sunk subsidiary seconds retained in the front plate recess by two feet, and screws going into the edge of the front plate. Accurate positioning of the dial ensured by pegs on either side of each dial foot set inside the rim of the front plate.

Blued steel hands, minute hand missing, seconds hand a replacement.

Movement
Front plate diam. 45·3 mm; back plate diam. 39·8 mm; frame h. 8·9 mm.

Frame: Three-quarter plate with four turned pillars, the back plate retained by blued steel screws whose threads do not correspond with those of cat. no. 107, otherwise movement similar. The front plate deeply recessed for the repeating and motion work under the dial. All the brass parts gilded. The movement was retained in its case by a single peg in the edge of the front plate and a screw opposite passing through the case middle and into the front plate, on the edge of the dial.

Fusee: Keywind fusee, with normal stop-work and maintaining power. The maintaining ratchet wheel steel. The polished steel setting-up-work with click spring on the back plate, the barrel arbor squared at both ends.

Going train: Apart from a larger great wheel with more teeth, the train is very similar to that of cat. no. 107 with high numbered pinions, well finished, and lightly crossed out gilded wheels, all with a square-bottomed tooth form.

Jewelling: All the pivots of the going train and escapement arbors in pierced jewels, the fourth, upper and escapement with endstones, all in screwed settings. The repeating runner pivots, without exception, in plain holes in the frame.

Escapement: A development of the Earnshaw detent escapement. The escape wheel brass, the remains of the detent mounted on a lyre-shaped polished steel frame carrying the banking screw (see also cat. no. 107). The polished steel impulse roller not jewelled, but with radial impulse face. The discharge roller jewelled, and with a flat for adjusting.

Balance: Bimetallic two-armed balance with gold compensation screws and quarter nuts on steel studs set in the rim. Diam. 16·0 mm, h. 1·49 mm.

Balance spring: Blued steel duo-in-uno spring with a terminal curve free sprung to a steel stud on the balance cock. Polished steel collet. (See cat. no. 111 for a similar spring.)

Minute repeating work: Of Swiss design if not manufacture, and showing many points of similarity with that of cat. no. 107, including the surprise piece constantly acting on the minute cam flirt.

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Repeating-train counts:
First wheel 50 teeth, pinions all six leaves each
Second wheel 40 teeth
Third wheel 34 teeth
Fourth wheel 30 teeth
Fifth wheel 30 teeth

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Contarde in 1937 (reg. no. CAI-1599).

Bibliography: Mercer 1981.

105 CHARLES FRODSHAM
1869

CHRONOMETER *Plates 67d–f, 68a–b*

Signature: On the back plate 'Cha^{s} Fordsham 84 Strand LONDON 01380 AD FMSZ', the last being obscured by the ring around the winding key. Also signed on the dial, just above the centre 'CHA^{s} FRODSHAM 01380 AD F.MSZ'.[1]

Case: Open face 18-carat gold case with the London hallmark for 1869 and the casemaker's J.W. in an oval. The cuvette and engine-turned back hinged to the middle, the later decorated with a reeded pattern. The pendant solid, and with the maker's mark TC. No push-piece or case springs. The cuvette marked with an arrow to show the direction of winding. The case back centre has been thinned down to remove a crest or monogram. Diam. 54·3 mm, overall h. 13·5 mm.

Dial and hands: Flat enamel dial with sunk subsidiary seconds and sunk centre of the up-and-down dial, fixed to the front plate by three feet and pins. The copper edge of the dial and the three feet have been gilded.

The minute and hour hands of gold and of spade design, the up-and-down and seconds hands of blued steel.

Movement
Ebauche marks 18, 2, 691, 01380.

Front plate diam. 46·1 mm; back plate diam. 43·2 mm; frame h. 7·4 mm.

Frame: Typical half plate construction with three turned pillars, the back plate retained by recessed blued steel screws. There is no separate bridge on the front plate under the dial, and there are a number of unfilled milled recesses and holes, possibly for fusee keyless work never fitted. The movement is held in its case by a peg and a single dog screw opposite, in the edge of the front plate.

Fusee: The fusee wound by a blued steel folding key fitted on the arbor square, the usual stop-work and maintaining power, with a steel maintaining ratchet wheel. The setting-up-work with a fine toothed blued steel ratchet wheel and two polished clicks with polished return springs fitted on the back plate. The barrel arbor with an extended square on that end only. The barrel with a small flange on the cover end. A small pinion on the lower end of the fusee meshes with a wheel carrying the up-and-down indicator hand.

Going train: The usual layout and design, the centre pinion hollow for the hand-set arbor carrying the cannon pinion and having a setting piece with grooves for the finger nail. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The upper pivot of the fusee arbor, and those of the going train and escapement arbors, in pierced jewels, those of the escapement and most unusually the fourth upper pivot with endstones. A diamond endstone set in a blued steel ring on the balance cock. All the jewels are well made and finished, the train jewels are *bombé*.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with arms and rim sunk below the level of the teeth, and with a dog screw to lock the wheel. The impulse roller made from a solid piece of clear sapphire, and with the impulse face leaning slightly towards a radial to the tip. The polished steel discharge roller with a small flat for adjusting, and jewelled in the usual way. The detent with polished sides, edges and top having a small half-round locking stone, and a gold passing spring held with a screw, planted with the centre line of the foot well inside a tangent to the locked tooth. Banking for the detent, against the locking stone pipe, provided by a small gold screw set in an arm projecting from a polished steel semicircular foot concentric with the balance staff.

Balance: Bimetallic two-armed balance with gold screws, and nuts at the ends of the arms. The other two quarter nuts of platinum. Diam. of rim 16·5 mm, h. 1·91 mm.

Balance spring: Blued steel duo-in-uno balance spring free sprung and with upper terminal curve to a diamond-shaped polished steel stud on the balance cock, and to a polished steel collet on the balance staff (see cat. no. 111 for a similar example).

Going-train counts:
Great wheel (fusee) 72 teeth, round bottom tooth form
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minutes wheel 36 teeth
Up and down pinion 10 leaves, wheel 60 teeth, 5 arms, not gilded

Provenance: Bequeathed by Mr F. R. S. Rogers in 1972 (reg. no. 1972, 9-3, 5).

Note

1. This is British work at its best. It is thought that 'AD F.m.s.z.' represents 1850, the year in which Frodsham began making high-quality watches.

Bibliography: Mercer 1981.

106 JOHN BENNETT
c. 1870

CHRONOMETER MOVEMENT *Plate 68c–f*

Signature: 'Jn^{o} Bennett 65 and 64 Cheapside LONDON NO 15425.' On the dial 'JOHN BENNETT 65 AND 64 CHEAPSIDE LONDON 15425'.

Dial and hands: Enamel dial, on the back 25.
Blued steel hands.

Movement
Ebauche marks 14 × 1, E.S. 25.
Front plate diam. 43·3 mm; back plate diam. 40·0 mm; frame h. 7·8 mm.

Frame: Half plate hunter calibre, with Chalfont fusee keyless work.[1] The frame built up on a thick front plate having three turned pillars and the back plate secured by screws. The front plate recessed under the dial to accommodate the fusee keyless work, the motion work, the setting-up-work, the up-and-down work and a detachable plate carrying the third, fourth and escapement lower bearings. The dial fixed directly to the front plate by three feet and pins. The movement retained in its case by a positioning peg and single dog screw.

Fusee: Fitted with the usual stop-work, and maintaining power with steel ratchet wheel and click pivoted between the plates. The stop-work spring and stop-piece made of a single piece of blued steel. The setting-up-work under the dial. The pivots of the fusee in detachable brass bushes.

Going train: The centre pinion hollowed out for the hand-set arbor carrying the pinion.

Jewelling: The third, fourth and escapement pivots running in pierced jewels, those of the escapement with endstones. Diamond endstone set in blued steel ring on the balance cock.

Escapement: Earnshaw type of detent escapement. The three-armed escape wheel of brass, the polished steel impulse roller jewelled so that the impulse plane is on a radial from the centre. The usual jewelled discharge roller mounted below the impulse roller. The polished steel detent is fitted with a half-round locking stone and the gold passing spring is held by a screw. The steel banking piece for the detent is concentric with the balance staff and carries a gold banking screw.

Balance: Bimetallic two-armed balance with gold compensation and quarter screws, straight crossbar. Diam. of rim 15·7 mm, h. 1·94 mm.

Balance spring: Blued steel helical spring of 6 turns, with terminal curves, free sprung to a steel stud on the balance cock. Brass rectangular collet on the balance staff.

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, steel minute wheel 30 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1940 (reg. no. CAI-1588).

Note

1. Chalfont fusee keyless work is illustrated and described in David Glasgow, *Watch and Clockmaking*, London, 1885, pp. 272-4.

107 CHARLES FRODSHAM
c. 1875

CHRONOMETER MOVEMENT *Plates 69a–f, 70a–d*

Signature: On the back plate 'Cha^{s} Frodsham 84 Strand London 02418'.

Case: No case, but was open face. The winding button and stem, winding pinion, the case springs and the two slides survive.

Dial and hands: The dial missing.
Dummy hour and minute hands. The up and down hand blued steel, the seconds hand missing.

Movement
Scratched on the front plate, under dial side 93079.
Front plate diam. 50·0 mm; back plate diam. 43·8 mm; frame h. 9·1 mm.

Frame: Three-quarter plate with five turned pillars, the back plate retained by blued steel screws whose threads do not correspond with those of cat. no. 104, otherwise a similar movement. The dial was retained by screws in the edge of the front plate and positioned by pegs pointing inwards from the edge into the recess in the front plate. The movement was retained in its case by two dog screws and a positioning peg. All the brass parts gilded. The escape cock has no less than four steady pins.

Fusee: Keyless fusee with normal stop-work and maintaining power, the maintaining ratchet wheel steel. The polished setting-up-work on the back plate with click spring, the barrel arbor squared at both ends.

Keyless work: Presumably a later addition after the back plate had been engraved as so much of the engraving is covered up by this complicated system. On turning the winding button in the direction of wind, the various steel wheels transmit the force to the largest steel wheel with a second set of upstanding triangular-shaped teeth. This particular wheel has a large central hole, and turns on an upstanding collar on the steel plate beneath it which is pivoted on a shoulder screw. It is held in place by the steel ratchet wheel mounted on the squared fusee arbor. These two wheels turn together and winding occurs. On reversing the direction of rotation of the winding button, the triangular-shaped teeth click over those of the ratchet wheel, the pivoted plate moving against a return spring to permit this.

To set the hands, two levers swing the pivoted plate with the largest wheel mounted on it against its return spring towards the centre of the movement. The triangular-shaped teeth are then completely disengaged from the ratchet wheel and those on the edge mesh with those of the central steel wheel. This wheel is on the end of an arbor passing through the hollow centre wheel and carrying the cannon pinion on the other end.

Up-and-down indicator: Also apparently an afterthought as it was added after gilding. A pinion on the end of the fusee arbor meshes with a six-armed wheel carrying the hand and pivoted on a stud, via two more pinions and another wheel. The surprise piece first has had to be modified to miss the arbor on which the two pinions are mounted, this has been quite crudely done by filing a piece out of it.

Jewelling: The pivots of the centre, third, fourth and escapement arbors in jewel holes with screwed settings, the escapement with endstones. The repeating runner pivots, without exception, in plain holes in the frame.

Escapement: Earnshaw detent escapement, with polished steel sunk escape wheel, the detent mounted on a lyre-shaped gilded brass frame carrying the banking screw and thus inaccessible without partially dismantling the movement.The polished steel impulse roller not jewelled, receiving impulse on a radial impulse face. The discharge roller jewelled, without a flat for adjusting. The detent foot is planted well inside a tangent to the locked tooth of the escape wheel. The detent with D-section locking stone and gold passing spring.

Balance: Bimetallic two-armed balance with gold compensation and quarter screws, except the last screw nearest the free end of each rim which is of platinum. One arm carries a pin pointing downwards and working with a balance stop device once operated by a slide in the band of the case. Diam. 17·5 mm, h. 1·54 mm.

Balance spring: A palladium spiral spring with overcoil and terminal curve to a steel stud on the balance cock. The collet of brass resembling a modern Swiss collet.

Index: With micrometer regulator and return spring, all of steel and finished to a very high degree. A pointed tool is used to turn the faceted head of the fine adjustment screw. A steel nut on the thread moves the index tail which moves over an index to make the watch go faster or slower as indicated on either side of the faceted nut.

Minute repeating work: Of Swiss design if not manufacture and of a type used by the firm of Le Coultre at Le Sentier and others. It is operated by a slide in the band of the case and the hammers strike on wire gongs. The repeating train wheels are gilded to a different colour to that of the other brass parts. The surprise piece acts on the minute flirt on the cannon pinion during the normal running of the watch and not only when the repeating work is operated as in later repeating work. This introduced a considerable and varying drag on the going train. In later repeating work the surprise piece only contacts the minute flirt when the repeating work is operated.

Going train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Up-and-down work:
The three pinions, 12 leaves each
The two wheels 30 and 72 teeth respectively, not gilded

Repeating train:
First wheel 64 teeth, first pinion 8 leaves, the other 4 of 6 leaves each
Second wheel 40 teeth each, the last pinion carrying a small steel fly of diamond section
Third wheel 34 teeth
Fourth wheel 30 teeth
Fifth wheel 30 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1598).

Note: A keyless work similar to the one fitted to this movment is described in the *Revue Chronometrique* 1876–7. It was manufactured by the Société Genevoise some time after 1868 following a competition for the design of a good medium quality watch 'of simple construction and mechanically sound, to be made available to a large number of purchasers and lending itself to bulk production'. Obviously simplicity is in the eye of the beholder!

108 FRODSHAM AND SON

c. 1875

CHRONOMETER MOVEMENT *Plates 70e, 71a–c*

Signed: On the back plate 'Frodsham and Son, Gracechurch St., LONDON 6950'. On the dial FRODSHAM, LONDON'.

Case: No case, but was open face.

Dial and hands: Enamel dial with sunk subsidiary seconds, fixed directly to the front plate by three feet and pins, two feet missing.

Blued steel hands, seconds hand missing.

Movement

Ebauche marks T+S 14×2.

Front plate diam. 42·5 mm; back plate diam. 38·0 mm; frame h. 6·3 mm.

Frame: Three-quarter plate with four turned pillars, the back plate retained by blued steel screws. Movement hinge, case catch and spring mounted on the dial side of the front plate. A large separate bridge on the front plate for the third, fourth and escapement bearings. All the brass parts gilded.

Fusee: Reversed fusee with stop-work and maintaining power, the maintaining ratchet steel. The setting-up-work on the back plate, the barrel arbor squared both ends.

Going train: Arranged in an anticlockwise direction when seen from the back. Well made and finished, the brass wheels gilded.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones, a diamond in the balance cock.

Escapement: A development of the Earnshaw detent escapement. The brass escape wheel with arms and rim sunk below the level of the teeth on the upper side. The polished steel banking piece mounted beside the detent and carrying a brass banking screw, providing banking for the detent against the head. The polished steel impulse roller not jewelled, the impulse face radial opposite a hole drilled for poising. The usual jewelled discharge roller with a flat for adjusting. Finely made detent with polished foot, gold passing spring held by a screw, and half-round locking stone, planted with the foot inside a tangent to the locked escape wheel tooth.

Balance: Bimetallic two-armed balance, the steel part of the rims blued, the screws gold. Diam. 17·5 mm, h. 1·38 mm.

Balance spring: Blued steel helical spring of about 5¾ turns, with terminal curves. Brass collet, polished steel stud.

Balance cock: As unusual one: in place of a normal cock on the front plate a brass piece is screwed, presumably for aesthetic purposes; a tapped hole just in front of it is left unfilled.

Going train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1600).

109 AUGUSTE BERTHOUD, ? Swiss

c. 1875

MARINE CHRONOMETER *Plates 71d–e, 72a–d*

Signature: On the dial 'Auguste Berthoud. No 293'.[1]

Box: The movement contained in a deep brass bowl with a heavy levelling weight screwed to the inside of the bottom, and an eccentric escutcheon disc over the winding hole on the outside. The bezel is held by two screws in the edge diametrically opposite each other, and there is a flat bevel-edged glass with a short blind hole on the outside to clear the cannon pinion. The bowl is suspended in gimbals in a well-made mahogany box. This has a lock at the front, a sliding panel over a circular aperture in the top, a lock for the gimbal ring and a tipsy winding key with reeded edge to the knob. A well-made hinge extends the width of the box. No carrying handles. Brass bowl: diam. 78·9 mm, overall h. 79·4 mm. Mahogany box: base 152 mm square, h. 142 mm.

Dial and hands: Engraved brass dial, matt silvered, the engraving filled with black wax, secured in a turned recess in the dial ring by a single screw below the centre of the seconds dial.

Blued steel hands.

Movement

Dial ring flange diam. 82·9 mm (reduced to 74·4 mm); dial ring thickness 14·4 mm; front plate diam. 63·0 mm; back plate diam. 63·0 mm; frame h. 16·1 mm.

Frame: Full plate construction with a detachable barrel bridge, four turned pillars secured to the front plate by brass nuts, the back plate secured by grained steel screws. There is a separate bridge on the front plate for the lower third, fourth and escape pinion arbor bearings. The lower balance staff pivot is carried in a potance screwed to the underside of the back plate. The thick dial ring is attached to the front plate by three shoulder screws under the dial. The brass frame components are finished with a pattern of fine scratches radiating from the centre.

Fusee: Reversed fusee with seven-turn Geneva stop-work on the dial side of the front plate. Harrison's maintaining power with a brass ratchet wheel, and integral detent and return spring. The setting-up-work planted on the barrel bridge, the arbor integral and unsnailed, the barrel flanged at both ends. The mainspring is hooked with an eye at both ends and there is a bride between cover and bottom. There is a brass dust cap on the winding square inside a brass tube secured by a foot to the back plate.

Going train: Well-made train with polished pinions and arbors, the wheels circular grained. The great wheel assembly held on the fusee by a steel flanged nut with left-hand thread.

Jewelling: The pivots of the fourth arbor in the front plate bridge and the escapement are in pierced jewels, the escapement with endstones. A diamond endstone set in a polished steel ring in the balance cock. The pierced jewels each set in a straight-sided brass bush without a flange.

Escapement: Spring detent escapement of late Earnshaw pattern, and very well made and finished. The brass escape wheel with the arms only sunk below the level of the rim and teeth. The steel impulse roller grained all over and set with a jewel leaning at about 30° towards a radial to the tip. The discharge roller with two adjusting flats, grained all over, and set with a flat-sided slip of jewel also leaning towards a radial to the tip. The detent very lightly made, with a round locking stone, and a gold passing spring held under a screw head. Banking is provided against a brass screw head set in a brass piece with an overhang over the escape wheel. Where the blade of the detent joins the foot the end of the foot is triangular in shape.

Balance: Bimetallic two-armed balance screwed to a steel collet on the balance staff. There are brass timing screws set in the rim near the ends of the arms, and brass segment weights each with a small steel clamping screw set in the edge between two larger steel screws. In the end of each weight is set a small brass screw for making fine adjustments to the compensation. Diam. of rim 26·4 mm, h. 2·1 mm.

Balance spring: Blued steel helical spring of $10\frac{3}{4}$ turns, without terminal curves, clamped concentrically at the full diameter to both the collet and the stud. The stud, with 3 small levelling screws, is held by a single screw on a brass arm secured to the underside of the balance cock.

Going-train counts:
Great wheel (fusee) 84 teeth, 7 turns of groove
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1953 (reg. no. CAI-1951). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Note

1. Tardy 1971 lists two August Berthouds: Charles-Auguste (1798–1876), son of Louis, was awarded a gold medal in 1849. The other, Auguste-Louis (1828–1910), nephew of Charles-Auguste, published a chronological list of memoirs and notes relating to the measurement of time taken from the proceedings of the Academie of Sciences 1666–1891 in *Revue Chronometrique*, Paris, 1892.

110 CALLIER

c. 1880

MARINE CHRONOMETER *Plates 72e–f, 73a–b*

Signature: On the dial 'Callier No. 763.'[1]

Box: The movement contained in a deep white metal (probably a nickel brass) bowl, with a heavy levelling weight screwed to the inside of the bottom. The winding hole is protected by a cover pivoted on a screw, which can be swung aside for winding. The heavy dial ring is turned to fit into the bowl with a wide flange resting on the top and screws at the side for fixing. The glazed bezel is missing. The gimbal ring, its lock and the box furniture are also made of the same white metal as the bowl.

The mahogany box has a glazed panel in the top under a hinged lid with catch operated by a push-piece at the front, similar to English practice. The front is centred with a rectangular ivory plate engraved 'Callier 763'. There are the usual lock and carrying handles. A tipsy key similar to that of Auguste Berthoud No. 293, cat. no. 109, fits in a hole in a corner gusset. There is also a slot in the right-hand side of the top of the box and lid, presumably for another type of key. Base 153 mm square, h. 153 mm.

Dial and hands: Flat engraved silvered brass dial, the engraving filled with black wax, secured by a single screw in a recess in the dial ring. The subsidiary seconds dial is in the upper half, and a reserve of going sector in the lower half.

Blued steel hands.

Movement

Dial ring flange diam. 82·4 mm (reduced to 74·5 mm); dial ring thickness 12·4 mm; front plate diam. 62·9 mm; back plate diam. 62·9 mm; frame h. 16·7 mm.

Frame: Very similar ébauche to that of Auguste Berthoud No. 293, cat. no. 109. The back plate secured by grained steel screws. The brass parts are considerably oxidised but were originally finished with a scratchy polish.

Fusee: Similar to cat. no. 109, but with different stop work. The mainspring is missing.

Going train: Similar to cat. no. 109, but the great wheel assembly held together by a flange and pin, with an integral index piece for the stop-work.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A diamond endstone in a blued steel ring in the balance cock. The jewel settings are of brass with flanges similar to English jewelling.

Escapement: Similar to that of cat. no. 109. The brass escape wheel gilded, the teeth slightly cut by impact with the impulse jewel. Both the detent and the banking assembly are missing.

Balance: A Frodsham/Hartnup bimetallic balance made up of a series of bimetallic strips screwed together at their ends and overlapping each other with a small clearance. Vertical threaded rods are fixed to the free ends of the final bimetallic strips for compensation weights, now missing. This type of balance is designed to cause the compensation weights to move towards the balance axis more rapidly in heat than they move away in cold, thus giving the possibility of eliminating the middle temperature error. There is an additional steel crossbar carrying brass timing and poising screws. The whole is fixed to a brass collet on the balance staff by a pair of steel screws. Diam. 34·5 mm; h. 12 mm (approx.).

Balance spring: Helical spring made of a palladium alloy, with a very high finish. 11 turns with a short terminal curve to the collet, clamped concentrically at full turns to a stud with 3 levelling screws. Screwed to a brass arm fixed to the underside of the balance cock.

Going-train counts:
Great wheel (fusee) 84 teeth, $7\frac{1}{2}$ turns of groove
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves (brass)
Hour wheel 54 teeth, minute wheel 56 teeth

Provenance: Ilbert Collection. Presented by Mr Gilbert Edgar C.B.E. in 1958. There seems to be no reference to this chronometer in C.A. Ilbert's inventory notebooks (reg no. CAI-1931).

Note
1. Tardy 1971, lists a Bernard Callier, Chronometers, in Paris 1848. Quai St. Michel, 1879. He quotes that he succeeded Winnerl in 1870, invented a new compensation balance for chronometers in 1879, received the cross of the Légion d'Honneur in 1893 and was succeeded by Emmanuel Boudeaud.

Bibliography: Bertele 1981, p. 241.

III CHARLES FRODSHAM

c. 1880

CHRONOMETER *Plates 73c–f, 74a*

Signature: On the back plate 'Cha^{s} Frodsham 84 Strand London 8645'. On the dial 'CHARLES FRODSHAM AD. F.m.s.z. 8645'.

Case: Later open face aluminium case, glazed on both sides. Originally cased as a half hunter.

Dial and hands: Enamel dial with sunk subsidiary seconds and up-and-down indicator secured directly to the front plate by three feet and pins.

Blued steel spade hands, the hour a double spade.

Movement
Ebauche marks R.D. (possibly Richard Doke) C.F., 12, 2°.

Front plate diam. 37·75 mm; back plate diam. 34·6 mm; frame h. 5·9 mm; front plate thickness 2·2 mm (reduced to 1·25 mm).

Frame: Unusually small half plate chronometer, with three turned pillars, the back plate retained by blued steel screws. The movement hinge and case catch mounted on the dial side of the front plate. A separate bridge on the front plate for the third, fourth and escapement bearings.

Fusee: Reversed fusee with integral stop-piece and return spring, and maintaining power, the maintaining ratchet wheel steel. The setting-up-work under the dial on the front plate, the barrel arbor squared on that end only. A pinion mounted on the reduced end of the fusee arbor pivot in the front plate drives the up-and-down work.

Going train: Similar to cat. no. 108, the centre pinion hollow for the hand-set arbor.

Jewelling: The lower centre arbor pivot, and those of the third, fourth and escapement arbors in pierced clear jewels. The upper fourth pivot and escapement with endstones, a diamond endstone in the balance cock.

Escapement: A development of the Earnshaw detent escapement. The brass escape wheel with arms and rim sunk below the level of the teeth in the upper side. The detent banked by a screw set in a short arm integral with a polished steel split ring set in a turned recess concentric with the balance jewel, and retained by a polished steel screw. The diminutive detent, just over 8 mm long, with polished foot, gold passing spring held by a screw, and round locking stone is planted with the foot well inside a tangent from the locked tooth. Polished steel impulse roller with radial impulse face not jewelled. Polished steel discharge roller without a flat for adjusting, jewelled in the usual way. Note that the axis of the detent is almost parallel with a vertical plane when the watch is pendant up. This refinement, also used by Victor Kullberg, reduces the effect of gravity on the escapement which produces positional errors.

Balance: Bimetallic two-armed balance with gold compensation screws, and quarter nuts on screws set in the rim. Diam. 15·5 mm, h. 1·58 mm.

Balance spring: Blued steel duo-in-uno with terminal curve to a polished steel stud, the spiral part of the spring pinned to a polished steel collet.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Up-and-down work: The large wheel carrying the hand has 60 teeth, driven by a wheel of 30 teeth, driven by a pinion of 10 leaves.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1833).

Note: It would be difficult to imagine any significant improvement to the proportions or finish of this movement which is still in mint condition. The escapement, balance and balance spring in particular can only be admired for their perfection.

112 PARKINSON & FRODSHAM
Late 19th century

CHRONOMETER MOVEMENT *Plate 74b–d*

Signature: On the back plate 'Parkinson & Frodsham Change Alley LONDON 4608'. On the dial, in the upper half 'PARKINSON AND FRODSHAM LONDON'.[1]

Dial and hands: Flat enamel dial with sunk subsidiary seconds, attached to the front plate by three feet and pins. The back marked faintly in the enamel 56 and 456, the latter very faint.

The minute and hour hands missing, the seconds hand blued steel.

Movement

Ebauche marks 14, 0, 4608.

Front plate diam. 42·5 mm; back plate diam. 39·1 mm; frame h. 7·3 mm.

Frame: Typical half plate construction with three turned pillars, the back plate retained by recessed blued steel screws. A large bridge on the dial side of the front plate carries the lower bearings of the third, fourth and escapement arbors. The movement was held in its case by a hinge at the XII position and a peg set in the edge of the front plate opposite. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work in a shallow recess on the dial side of the front plate, the barrel arbor with an extended square on that end only. The barrel with a very slight flange on the cover end.

Going train: The usual construction but the layout unusual in that the fourth wheel is placed below instead of above the third. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A diamond endstone set in a blued steel ring on the balance cock. The train jewels with slightly curved faces against the pivot shoulders.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with arms and rim sunk below the level of the teeth. The polished steel impulse roller with radial impulse plane. (See Charles Frodsham, cat. no. 111, for a very similar example.) The polished steel discharge roller without an adjusting flat, and having a wedge-shaped jewel and corresponding slot in the edge of the roller. The detent with polished top to the foot, half-round locking stone and a replacement steel passing spring held with a screw, banking by the locking stone pipe against a screw set in a brass block under the escape wheel. The foot of the detent planted inside a tangent to the locked tooth.

Balance: Bimetallic two-armed balance with gold screws, except the timing screws at the ends of the arms which are steel. Diam. of rim 15·5 mm, h. 1·77 mm.

Balance spring: Blued steel spiral spring of 9 turns with an overcoil and terminal curve, free sprung to a stud on the balance cock and a round brass collet.

Amplitude limiting device: At a certain amplitude a steel pin standing up from one balance arm will be touched by the outer coil of the balance spring and produce a braking effect.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; Ilbert purchased this movement in the Caledonian Market in 1932 (reg. no. CAI-1741).

Note

1. The firm of Parkinson and Frodsham was founded in about 1800 by William Parkinson and W. J. Frodsham, both admitted to the Clockmakers Company in 1802. At 4 Change Alley until 1842, the name appears in the *City of London Directory* in 1873, at the same address and again in 1907 at 5 Budge Row.

113 ALEXANDER WATKINS
Late 19th century

CHRONOMETER MOVEMENT *Plates 74e–f, 75a*

Signature: On the back plate 'Alex^{r} Watkins, 67 Strand LONDON No. 4682'. On the dial 'WATKINS 67 STRAND LONDON'.

Dial and hands: Flat enamel dial on the back faintly in red XII and a line showing its position. The centre part of the subsidiary seconds dial sunk, the dial secured directly to the front plate by three feet, one broken, and pins.

Gold minute and hour hands, hour hand tip broken off, blued steel seconds hand.

Movement

Ebauche marks 12, 2.

Front plate diam. 40·8 mm; back plate diam. 36·3 mm; frame h. 7·0 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate secured by recessed blued steel screws. The movement was fixed in its case by a hinge screwed to the front plate under the dial, and a case catch and spring opposite. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power with steel maintaining ratchet wheel. The setting-up-work fitted in a shallow recess on the dial side of the front plate, the barrel arbor with an extended square on that end only.

Going train: Typical layout and construction, the brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones.

A diamond endstone set in a blued steel ring on the balance cock.

Escapement: A development of Earnshaw's spring detent escapement, the brass escape wheel with arms sunk below the level of the rim and teeth. The polished steel impulse roller with radial impulse surface, the usual jewelled polished steel discharge roller without an adjusting flat. The unusually long detent overhanging the fourth wheel fitted with a triangular locking stone and a gold passing spring held by a screw. Banking for the detent provided by a gold block screwed and steady pinned to the front plate, and with a small protruberance touching the lower end of the locking stone pipe.

Balance: Bimetallic two-armed balance with gold quarter and compensation screws. Diam. of rim 13·3 mm, h. 1·33 mm.

Balance spring: Blued steel helical spring of comparatively large diameter, and having 5½ turns, with terminal curves. A polished steel stud on the balance cock, and a brass block-shaped collet.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 60 teeth, 5 arms
Escape pinion 6 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth.

Provenance: Ilbert Collection; purchased by Ilbert from Benson in 1935 (reg. no. CAI-1753).

114 WEBSTER AND SON

Late 19th century

CHRONOMETER MOVEMENT *Plate 75b–d*

Signature: On the back plate 'WEBSTER & SON Birchin Lane LONDON No. 9572'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, secured to the front plate by three short feet and pins.
Blued steel hands.

Movement
Ebauche marks JM, 5021, 10, 0.
Front plate diam. 39·0 mm; back plate diam. 34·5 mm; frame h. 6·5 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate secured by recessed blued steel screws. The thickness of the front plate has been so reduced, particularly at the centre, that it has started to buckle. The movement was fixed in its case by a hinge screwed to the dial side of the front plate, and by a case catch and spring opposite. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, with steel maintaining ratchet wheel. The setting-up-work fitted in a shallow recess on the dial side of the front plate, the barrel arbor with an extended square on that end only. The barrel with a flange on the cover end.

Going train: Typical layout and construction, the brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The fourth arbor lower pivot and the escapement pivots in pierced jewels, those of the escapement with endstones. A diamond endstone in a blued steel ring on the balance cock.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel with arms sunk below the level of the rim and teeth. The polished steel impulse roller with a large V-shaped notch and radial impulse surface. The polished steel jewelled discharge roller, without an adjusting flat, sandwiched between the impulse roller and the balance. The detent held by a screw in a slot at the end of the arm of a steel frame with the banking screw set in a second shorter arm (see cat. nos. 104 and 107). A triangular locking stone and gold passing spring fitted to the detent, the latter held with a screw.

Balance: Bimetallic two-armed balance with four steel screws, the remaining compensation and quarter screws gold. The steel part of the rim has been blued. Diam. of rim 12·5 mm, h. 1·23 mm.

Balance spring: Blued steel spiral spring of 12¾ turns without overcoil or terminal curve, free sprung to a polished steel stud screwed to the back plate, and a round brass collet.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves.
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1935 (reg. no. CAI-1754).

115 RICHARD ATTENBOROUGH

1900

CHRONOMETER WITH REPEATING WORK (8-Day) *Plate 76a–d*

Signature: On the dial RICH$^{\underline{D}}$ ATTENBOROUGH 68 OXFORD STREET LONDON. 3051'. On the back plate 'Rich$^{\underline{d}}$ Attenborough, 68 Oxford Street London N$^{\underline{o}}$ 3051'.

Case: Original case missing, the movement now contained in a brass drum with glazed lid, and having a slide to operate the repeating work.

Dial and hands: Flat enamel dial held by two rectangular feet and screws set in the recessed edge of the front plate. The dial feet are positioned by brass pins also set in the edge of the front plate, as was customary in English repeating watches at the end of the eighteenth and in the early part of the nineteeth centuries. The chapter ring offset below the centre dial. Sunk subsidiary seconds dial soldered in place.

Blued steel hands.

Movement

Ebauche marks E.G. on the dial plate under the dial.

Front plate diam. 46·2 mm; back plate diam. 41·9 mm; frame h. 9·6 mm.

Frame: Three-quarter plate construction with five turned pillars, the back plate retained by blued steel screws. The front plate deeply recessed under the dial to accommodate the repeating work. All the brass parts frosted and gilded.

Going barrels: Two keywound going barrels, each provided with four-turn Geneva stop-work, and ratchets and clicks. The tails of the clicks left long and carried to the edge of the front plate for ease of letting down the mainsprings.

Going train: Arranged to run for eight days. The great wheels on the barrels mesh with an intermediate pinion whose wheel meshes with the offset centre pinion. The remainder of the train is conventional, but laid out almost in a straight line. The pinions are well polished, the brass wheels polished flat. All the wheel teeth and pinion leaves are of square bottom tooth form except the barrel teeth which are of round-bottom tooth form. The repeating train wheels are frosted and gilded. The seconds pivot broken.

Jewelling: All the pivots of both the going and repeating trains are in pierced jewels. The escapement pivots also have endstones. All the jewelling on the back plate set in brass settings and retained by blued steel screws. The jewels are of the highest quality with olived holes, and are of a pale purple colour.

Escapement: Remarkably small and well executed Earnshaw type of spring detent escapement. The detent is carried on a gilded brass mounting overhanging part of the train. Banking for the detent is against a semi-circular brass piece concentric with the lower balance jewel. One end of this piece banks the detent, the other is adjustable by a screw carrying a pin passing into a slot. There is also a locking screw. The rollers are of typical construction, in polished steel, the impulse jewel set on a radial to the tip. The detent is only ten millimetres in total length, the top of the foot polished, the remainder grained, the spring part divided in half by an elongated hole.

Balance and spring: Ordinary type of bimetallic balance with gold and platinum screws. Diam. 21·0 mm, h. 1·0 mm. Blued steel helical balance spring of 7½ turns, with terminal curves, free sprung to a stud on the balance cock.

Repeating work: Minute repeating work typical of the kind made in Switzerland. The steel work polished on the side facing the dial, otherwise straight grained. The repeating train of runners pivoted in the frame. There are no minute divisions around the edge of the front plate under the dial as is usual in later work. The gongs are made from the solid i.e. the foot and wire are all one piece, a characteristic of top grade work, and have a very good tone.

Going-train counts:
Great wheels (barrels) 96 teeth
Intermediate pinion 12 leaves, wheel 60 teeth, 5 arms
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 60 teeth, 5 arms
Escape pinion 6 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Repeating-train counts:
Great wheel 42 teeth
First pinion 6 leaves, wheel 36 teeth
Second pinion 6 leaves, wheel 34 teeth
Third pinion 6 leaves, wheel 32 teeth
Fourth pinion 6 leaves, wheel 30 teeth
Fly pinion 6 leaves

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1585).

116 M. B. LEE AND SON

c. 1900

CHRONOMETER MOVEMENT *Plate 76e–f*

Signature: On the back plate 'M. B. Lee and Son 155 Oxford Street MANCHESTER No. 3334'. On the dial 'CHRONOMETER' 3334'.

Dial and hands: Flat enamel dial, retained to the front plate by three feet and pins.

Blued steel hands, the hour hand broken.

Movement

Ebauche marks 16 2

Front plate diam. 45.0 mm; back plate diam. 41·7 mm; frame h. 7·0 mm.

Frame: Typical half plate construction, with three turned pillars, the back plate retained by three recessed blued steel screws. The movement held in its case by a small hinge and a pin opposite passing into a hole in the middle of the case instead of a catch. The brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work under the dial on the front plate, the barrel arbor with an extended square on that end only.

Going train: The centre arbor hollow for the hand-set arbor carrying the cannon pinion. The train well finished, the brass wheels gilded.

Jewelling: Only the pivots of the escape arbor and balance staff in pierced jewels, with endstones, the diamond endstone in the balance cock missing.

Escapement: A development of the Earnshaw detent escapement. The brass escape wheel with rim and arms sunk below the level of the teeth. The jewelled discharge roller without an adjusting flat sandwiched between the radially jewelled impulse roller and the back slope of the balance staff. The detent with its passing spring missing and the locking stone replaced by a piece of brass wire. Banking for the detent provided by a brass piece screwed in a recess on the end of the escape cock.

Balance: Bimetallic two-armed balance with gold compensation and quarter screws. The steel parts do not appear to have been blued. Diam. 18·5 mm, h. 1·4 mm.

Balance spring: Free sprung, blued steel, open coil, spiral spring of $10\frac{3}{4}$ open turns and with an overcoil and theoretically incorrect terminal curve. A brass collet on the balance staff and a diamond-shaped stud on the balance cock.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert in 1931 (reg. no. CAI-1606).

117 GEORGE EDWARTS

1903

CHRONOMETER *Plate 77a–d*

Signature: On the barrel bridge 'George Edwarts 005'. On the back plate 'CHRONOMETER MAKER TO THE ADMIRALTY LONDON'.

Case: Open face silver case with the Chester hallmark for 1903 and the maker's mark J.M.K. surmounting a I. The inner dome numbered 005. The middle with fine reeding, the back engine-turned with an oval central cartouche and opening with a single fly spring, and a case catch and spring operated by a push-piece in the pendant. The pendant hallmarked and with the maker's mark CH. Diam. 53·5 mm, overall h. 20·4 mm.

Dial and hands: Flat enamel dial with sunk central portion and subsidiary seconds, and inscribed CHRONOMETER in the upper half of the centre, secured directly to the front plate by three feet and pins. On the back of the dial in the enamel 86.

Blued steel hands, all replacements.

Movement

Ebauche marks 18 4 W.B., and 005, 005 also on the train bridge.

Front plate diam. 46·6 mm; back plate diam. 41·2 mm; frame h. 8·2 mm.

Frame: Full plate construction with four turned pillars,[1] the back plate retained by two blued steel screws and two pins. A detachable barrel bridge, no dial plate but the front plate recessed for all the under dial work. The movement hinge and case catch fitted on the front plate under the dial. There was once a dust cap, now missing. All the brass parts gilded, probably electro-gilded after acid etching.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work fitted on the dial side of the front plate, in a shallow recess. The barrel arbor with an extended square on that end only.

Going train: The usual layout and construction, the brass wheels burnished, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the fourth and escape pinion arbors in pierced jewels, those of the balance staff in pierced jewels with endstones.

Escapement: A form of pivoted detent escapement. The brass escape wheel left the full thickness, and locked by a triangular, clear sapphire, locking stone. The steel detent pivoted in the frame, the pivoting point planted well inside a tangent to the locked tooth. A blued steel spiral return spring acts by the free outer end resting against the detent. The passing spring also of blued steel pinned into a block set in the short detent tail. Banking provided by a strong brass pin in the path of the detent tail. The impulse roller with polished edge and notch, the impulse face leaning slightly towards a radius to the tip. Grained steel discharge roller with a jewel.

Balance: Bimetallic two-armed balance with brass screws. Diam. of rim 17·4 mm, h. 1·62 mm.

Balance spring: Blued steel spiral spring of $10\frac{1}{2}$ turns, without an overcoil or terminal curve, pinned to a polished steel stud on the balance cock. 5 scratched on the underside of the cock. A polished steel index fitted on a boss concentric with the balance upper bearing.

Going-train counts:
Great wheel (fusee) 75 teeth
Centre pinion 10 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 10 leaves, wheel 75 teeth, 5 crossings
Escape pinion 10 leaves, wheel 16 teeth, 4 crossings
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, brass minute pinion 12 leaves
Hour wheel 48 teeth, minute wheel 42 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1734).

Note

1. This is exceptionally late for a full plate movement; it is possibly recased.

117A HAMILTON WATCH COMPANY

c. 1962

MARINE CHRONOMETER *Plates 77e–f, 78a–f, 79a–d*

Signatures: On the front of the box 'Hamilton Watch Co.

Lancaster, Pa, U.S.A.'. On the dial 'HAMILTON LANCASTER P.A., U.S.A.' and the number 'ZE 10228'. On the back plate 'HAMILTON WATCH CO LANCASTER, PENNA. Model 21. 14 jewels Made in U.S.A.' and the number 'ZE 10228'.

Case: The movement contained in a brass bowl. The winding hole is protected by a circular cover which can be moved aside to reveal it and which is returned by a spring. The heavy dial ring, also of brass, drops into a recess in the bowl top and is positioned by a peg. The glazed bezel clamps the movement into the bowl. The gimbal ring, its lock and the box furniture all of brass, the gimbal lock unusually fitted with two tensioning springs so as to make it a spring fit into the slot of the lock bracket that is on the bowl.

The brass bound mahogany box has a glazed panel in the top under the hinged lid. Inside the lid is fixed a panel:

> NOTICE
>
> WINDING: Wind chronometer regularly every day.
>
> SETTING: Set hour and minute hands in forward direction – never backward. Do not interfere with second hand at any time.
>
> TRANSPORTING: In preparing chronometer for shipping, permit instrument to run down, wedge balance wheel as illustrated, remove chronometer and gimbal system from box, and pack in separate container with adequate padding.
>
> [Two illustrations showing the wedging of the balance.]
>
> To carry chronometer for short distances in operating condition, lock gimbal system and handle carefully.
>
> CAUTION: Never impart a violent rotary motion to chronometer.
>
> Do not transport chronometer when fully run down without first wedging balance wheel as illustrated above.

The hinges are continuous, that is of the piano hinge type. The lid catch is operated by a sideways movement of the small knob. The glazed middle portion carries a brass label with the signature as detailed above. There is no lock for the main box just a catch as for the lid. The carrying handles are cast and not recessed into the box. In the bottom of the box is another label with: 'CAUTION This instrument was designed for maritime navigation, and to be run only in the flat position. All factory rating tests have been made accordingly. To ensure accurate performance, always keep watch in horizontal dial up position. WHEN SHIPPING – always remove cased movement from gimbal ring and ship separately from mounting box'.

A tipsy key sits in a gusset in the box corner. Size of box 192 mm square × h. 190 mm.

Dial and hands: Flat silvered dial, the markings produced by etching and filling black. The dial secured by three screws with polished heads from the back, the screw ends visible at the dial edge but not polished, being hidden by the bezel. The reserve of going in the top half of the dial, the seconds in the lower. Signed as detailed above. Arabic numerals. The hour and minute hands of brass painted black, the seconds blued steel.

Movement

Dial ring flange diam. 106·6 mm reduced to 97·7 mm; dial ring th. 9·0 mm; front plate diam. 97·8 mm; back plate diam. 87·7 mm; frame h. 46.6 mm.

Frame: Of nickel-silver, the screws steel with polished heads. The nickel-silver parts finished with a wave decoration in straight lines. The pillars not riveted in but secured by screws at both ends. All the bearing holes bushed with gilded brass bushes or with jewels set in gilded brass chatons. The front plate numbered ZE 10228. The back plate unusual, being supported by three pillars only, the plate being cut away where it would normally be supported by the fourth pillar. Two large cut-outs allow for the removal of both the barrel and fusee once the barrel bridge has been removed. The polished steel setting up ratchet wheel is on the barrel bridge. The ratchet also of polished steel and controlled by a spring. The whole retained by a subsidiary bridge. The disc excluding pipe for the fusee arbor fitted with a rubber grommet. There is a separate bridge for the escape wheel lower pivot in the back plate which greatly facilitates assembly. The upper third and fourth jewels in a bridge secured to the front plate.

Fusee: Harrison's maintaining power with a brass ratchet wheel. The fusee gilded. The polished steel detent with an integral wire spring standing parallel to the arbor. The stop actuated by the chain which pushes a spring-loaded slider in the fusee so that it contacts a stud in the barrel bridge.

The barrel unusual, the lid being retained by five small screws. The barrel flanged at the cover end. The solid steel arbor snailed and 13 mm in diameter.

Barrel: Inside dim. 38 mm, internal available h. 15·3 mm, mainspring h. 15·0 mm, th. 0·44 mm. The mainspring fitted with a brace.

Train: Gilded throughout but wheels finished with a rather coarse straight grain. Pinions well polished all over, the centre alone with an undercut.

Jewelling: 14 jewels in all: lower third, upper and lower fourth, escape top and bottom, both with endstones. Two pierced balance jewels with endstones, that in the balance cock diamond, the other endstone ruby. Impulse, locking and discharge jewels.

Escapement: Spring detent escapement of the Earnshaw type but with some continental features. The brass escape wheel with only the teeth full thickness. The impulse roller set with a jewel, its acting face radial. The discharge roller unusual being made as a long split collet with two flats for adjusting and set with a jewel with a radius to the back of the acting part of the tip. The detent built up on nickel silver block which is steady pinned and screwed and made so as to provide an adjustable stop for the detent; this extended portion carries a gold stop against which the block that carries the locking jewel banks. The detent is wide – 3·00 mm – and the spring part is composed of two narrow strips each 0·5 mm wide and 3·5 mm long. The passing spring is supported by a bracket some 2·4 mm in height, the horn being bent and with a nib for the spring to bank against. The locking stone D-shaped and pinned into its hole in a square section portion of the detent. A slot in the end of the detent receives the head of a screw in the end of the detent block. With the detent securing screw slackened off, turning the screw in the block adjusts the depth of the detent with respect to the balance. The locking stone acts on the tooth after that which has just given impulse. The detent gilded.

Balance: Ovalising uncut balance with stainless steel rim and invar arm, the arm being brazed to the rim with signs of the brazing still visible. Ni-Span-C spring of 14 full turns with terminal curves. The spring clamped at both ends to a stud steady pinned to the cock and to a poised split stud mounted on the balance staff. The staff pushed into a flanged bush on which the balance sits, the balance sandwiched between the bush and a shaped washer with two screws.

The impulse roller of steel polished all over and with a ruby impulse pallet set with its impulse face radial. Three holes in the roller, the one opposite the stone being for poising purposes. The balance with eight compensation screws and four timing nuts; two for fine adjustment set to the side of the arm. The rim very thin – 0·6 mm. Rim diam. 35·5 mm; overall diam. 40·5 mm. h. 4·1 mm.

Going-train counts:
Great wheel (fusee) 90. Fusee with 8 turns
Centre pinion 14 leaves, wheel 90 teeth, 5 crossings
Third pinion 12 leaves, wheel 80 teeth, 5 crossings
Fourth pinion 10 leaves, wheel 75 teeth, 5 crossings
Escape pinion 10 leaves, wheel 16 teeth, 4 crossings
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves (brass)
Hour wheel 54 teeth, minute wheel 56 teeth
Up-and-down pinion 12 leaves
Up-and-down wheel 120 teeth, 5 crossings

Provenance: Purchased in 1988 (reg. no. 1988, 4–10, 2).

Note:

According to the seller Mr Raymond Mellor, one-time Managing Director of Hamiltons U.K. Branch, the chronometer was finished especially for him from the last parts available at the factory in the U.S.A. This is therefore the last of this series of chronometers to be produced. It comes complete with rate sheet and service manual.

II.vii (cat. nos 118-130)

EARLY APPLICATIONS OF THE LEVER ESCAPEMENT

All the examples in this section have fusees with the exception of the 'perpetuals' by A. L. Breguet (cat. nos 122 and 123) for reasons that are outlined in those entries.

As a result of Count von Brühl's efforts to publicise Mudge's original escapement various makers tried to use it in one of several alternative forms including Josiah Emery, Richard Pendleton, John Leroux, John Grant, George Margetts, Francis Perigal, Taylor (whose initial is not known), and T. Cummins (possibly Thomas) in England, and A. L. Breguet and Richard Robin in Paris.

The English makers must have found the escapement difficult to make, and this probably accounts for the variety of different forms adopted. Quite apart from the difficulty of making the parts themselves, there was the problem of the geometry and the choice of the different angles when designing the escapement. No one knew what the most suitable values for these angles should be.

With the exception of John Leroux, to whom credit is due, none of the early makers introduced 'draw' into their escapements. This is the slight inclination of the locking surfaces of the pallets so that when locked they tend to move towards the wheel. This prevents any tendency for the fork to rub on the roller(s) on the balance staff during the supplementary arc of the balance, and greatly improves the escapement. Without draw a pocket timekeeper fitted with a lever escapement is liable to random errors in timekeeping depending upon how much disturbance there is to the balance.

Makers of early lever watches were reluctant to use draw, probably because it reintroduced one of the disadvantages of the verge escapement – recoil.

To effect draw the train has to be reversed which subtracts energy from the balance and, all things being equal, this requires the use of a stronger mainspring. The solution tried by the early makers was to counterpoise the lever and trust to inertia to keep the lever safely banked. This of course was a forlorn hope and in the nineteenth century makers universally accepted the necessity for draw.

Another solution was tried, for Berthoud and Breguet sometimes used a light spring resting on a cam which is fitted to the arbor of the lever.[1] The geometry is such that the lever is urged towards the banking pin as the spring end passes the high point of the cam. Although as effective as draw the obvious disadvantage is the friction that occurs throughout the escapement action.

Lift is the angle through which the lever of the lever escapement travels during impulse. The lift may be divided between the pallets and the escape wheel teeth, for example cat. no. 130, or may be all on the pallets as in cat. no. 122, or all by the escape wheel teeth (when pointed pallets are employed) as in cat. no. 118. Ultimately the divided lift escapement was to become the only type used for precision work. However the English used the ratchet tooth lever escapement, where the lift is on the pallet, for virtually all of their work.

DISPOSITION OF THE THREE MAJOR COMPONENTS

The early lever escapements were arranged so that their arbors formed a triangle but may be arranged in any way that is convenient without altering the function. Later practice was to arrange the arbors in a straight line although this was hardly ever done in English work; cat. no. 123 is an example of the straight line escapement.

THE BALANCE ROLLER

The earliest lever escapements, including Mudge's lever watch, had a type of double roller on the balance staff. The upper part carried the impulse pin or jewel(s) and the lower part provided the safety action in conjunction with the guard pin or dart. This is the arrangement in all the examples in this section. The shape of the impulse pin is also of importance and will be discussed in the technical introduction to the next section.

OIL RETENTION

The lever escapement has to be oiled on the impulse faces of the pallets but unfortunately conditions are not favourable for the retention of this oil which is constantly being swept away during the action of the escapement. There are examples in the collection of various modifications to the escape wheel teeth to help to keep the oil where it should be. The teeth of the escape wheels of cat. nos 122, 123, 124 and 126 are slotted to retain oil. Every fifth tooth of the escape wheel of cat. no. 130 is drilled with a conical hole to hold oil. This hole is large at the back of the tooth and tapers to a small hole just below the locking corner. The James Ferguson Cole watch (Section II, viii) cat. no. 131) has an escape wheel with teeth that have both slots and drilled holes. One tooth has broken because of the resulting weakness. Such answers are costly and were not used to any extent. The problem of retaining oil at the pallet jewels was never successfully solved, despite the introduction of sophisticated specialised oils and of treatments of the surfaces to prevent the spreading of oils.

If the early levers made in England and those made by A. L. Breguet are compared one can only be struck by the latter's astonishing mastery of the problems involved. It is surprising, though, that Breguet did not introduce draw until quite late.[2] However, he does not seem to have turned his full attention to the problems of marine and pocket timekeepers until after he was appointed 'Horloger de la Marine' in 1815, and even then he used the detent escapement almost exclusively.

The link between the early lever escapements for precision use up to about 1800 and the continued use and development of the escapement in England for more mundane applications can be see in the work of Peter Litherland and Edward Massey in Liverpool. Litherland took out his patents in 1791 (No. 1830) and 1792 (No. 1889) for various versions of his rack-lever escapement.[3] In the second patent he clearly stated that the escapement was for application in timekeepers to be used at sea, where it would clearly be cheaper to make and repair than the escapements then in use. Although he must have been disappointed in this expectation, the escapement gave perfectly adequate results in ordinary watches and a considerable number were made in and around Liverpool.[4] Later Edward Massey worked on improvements to the fork and roller action, in place of the rack and pinion of Litherland's escapement. The traditional English ratchet tooth lever escapement with table roller evolved from this work, and the escapement parts were manufactured in Liverpool and Prescot throughout the nineteenth century and the early years of the present century.

Notes:

1. George Daniels, *Watchmaking*, London, 1981, p. 213.
2. Daniels 1975.
3. Before Litherland patented the rack lever in 1791 a version of it using a kind of recoil escapement and with a straight leaf spring acting on the pallet frame instead of a balance spring was invented by the Abbé d'Hautefeuille (1647–1724) in 1722. This invention did not appear to lead to any further development (Daniels 1975, pp. 304–13).
4. Chamberlain 1941, pp. 57–62. See R. V. Mercer, 'Peter Litherland and Co', *AH*, June, 1972, for further information.

118 JOHN LEROUX (1744–1808)[1]

c. 1785

LEVER WATCH MOVEMENT *Plates 79e–f, 80a–e, 81a*

Signature: On the back plate 'Leroux Charing Cross London 3153'.

Dial and hands: Later slightly curved enamel dial without subsidiary seconds, secured to the dial plate by three short feet and pins.

No hands.

Movement

Dial plate diam. 49·4 mm; front plate diam. 46·6 mm; back plate diam. 45·0 mm; frame h. 9·8 mm.

Frame: Full plate construction with four turned pillars, two passing through the back plate and with pins, and two with recessed screws (one beneath the foot of the balance cock) in the back plate passing into them to retain the back plate. Separate potances for the lower bearings of the escape wheel and pallet arbors and the balance staff, that of the escape wheel arbor passing through a shaped hole in the front plate. The dial plate once carried the movement hinge, and is fixed to the front plate by three feet and pins. The case catch and spring removed from the front plate under the dial. There are a number of unused holes in the frame. All the brass parts gilded. A very heavy dust cover with the punched maker's mark IB held by a clip on two long studs on the back plate.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining detent missing, the rachet wheel steel. The setting-up-work under the barrel on the inside of the front plate. The barrel arbor with an extended square on the front plate end only. The barrel flanged at the cover end with a relief on the other end to miss the steel maintaining ratchet wheel with a very small clearance.

The fusee assembly is unusual in that the maintaining spring is attached to the recessed underside of the maintaining ratchet plate, and acts on a block fixed in a sink in the great wheel. The maintaining ratchet plate has a ring left standing on its underside, fitting into a recess in the great wheel, and carries only a single winding and return spring on the top surface.

Going train: The gear ratio between the centre wheel and the fourth pinion is 60:1 so the fourth arbor could have carried a seconds hand. The end of the lower pivot is of comparatively large diameter and the end rougher than the others so it may well have originally been extended to carry a seconds hand and have been shortened when the replacement dial was fitted. The pinions and arbors well finished with deep undercuts in the pinions on the sides facing the pivots, the opposite sides polished flat with the arbors, which are also polished. The brass wheels gilded.

Jewelling: All the going train arbor pivots run in pierced jewels in screwed settings. The jewels themselves are pierced discs, and left flat on both sides. Those for the fusee arbor pivots have virtually no sink for the oil, the centre arbor lower jewel is similar. The remainder do have oil sinks of varying depths. The pivots of the escape wheel arbor and balance staff are in pierced jewels with endstones, a diamond endstone in a polished steel ring on the balance cock. The pallet arbor pivots are run in small jewels similar to those of the going train, but set in adjustable settings with screwdriver slots for altering the escapement centre distances, a most unusual arrangement. The endstone jewels are all set slightly recessed in their settings, with the exception of the diamond balance endstone set flush with the lower side of its steel plate.

Escapement: Early lever escapement (figs 5 and 5a), one of the first, if not the first, to have 'draw'. Steel escape wheel resembling a flat wheel for a cylinder escapement, all surfaces polished including the crossings and all the surfaces of the teeth. The bottom pivot carried by a potance. The impulse pin a piece of sapphire dovetailed to its roller and with a cylindrical projection to work with the fork. Safety action provided by a small notched roller on the balance staff above the impulse roller, working in conjunction with a dart formed on the end of a steel piece screwed to the fork and incorporating an integral poising arm. Banking provided by a piece of ruby set in the tail of the fork working between banking screws set in blocks on a brass piece screwed and pinned to the underside of the back plate. The pallet frame made from a block of steel milled out on the inside to allow the escape wheel teeth to pass through on its axis. The pallet staff in two pieces set one on each side of the frame, and carrying the fork on the longer end. The pallet stones dovetailed in place and made of pale ruby. The locking surfaces of both pallets are inclined to give draw, and all the impulse is given by the long impulse surfaces on the wheel teeth. The bottom end of the pallet arbor supported by a potance.

Balance: Steel four-armed wheel with two screws to hold it on a collet on the balance staff. Blocks left standing on the rim for two timing screws and two screws restricting the free outward movement of the bimetallic strips. Thermal compensation provided by a system resembling a two-armed bimetallic balance, mounted friction tight on the balance staff above the balance wheel. The two bimetallic strips are apparently soldered to pieces left standing on the ends of the crossbar, and roughly bent into a circle. Each bimetallic strip is made up of steel and brass, either fused or soldered together. At the free ends a square block of brass is left integral, and carrying a brass disc held on with a central blued steel screw. The general appearance is that of an experimental balance crudely executed. The bimetallic strips seem to be so thin and flimsy that the purpose of the restricting screws might well have been simply to prevent them flexing too far in the long arcs. The watch would certainly not have been capable of a sufficiently good performance to detect a secondary error of compensation as suggested in Chamberlain 1941, p. 48.

Balance spring: Conical steel spring either hardened and tempered, without cleaning up or else hand rolled, pinned to a brass collet (this may be the first conical spring). The steel stud screwed to a brass arm overhanging the balance and itself screwed to the back plate by a single screw and without a steady pin.

Balance cock: With three turned steps and without any decoration.

Going-train counts:
Centre pinion 14 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work
Cannon pinion 12 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 48 teeth

Provenance: Mr Hugh Todhunter; Ilbert Collection; given to Ilbert by Mr Todhunter in 1934. Paul Chamberlain relates that he saw this watch when it belonged to Mr Hugh Todhunter of Broadway, who later gave it to Ilbert. Another similar unnumbered watch, the only other one known, is in the collection of the Clockmakers' Company. It has its original case, hallmarked 1785–6 (reg. no. CAI-1038).

Note

1. John Leroux worked *c.* 1750–1805. Free of Clockmakers' Company 1781.

Bibliography: There is a drawing of the escapement of the unnumbered watch (referred to under *Provenance*) in Chamberlain 1941, p. 49; also in *Horology*, Los Angeles, vol. III, no. 6, September 1936.

119 JOSIAH EMERY
1786

LEVER WATCH *Plates 81b–e, 82a–f, 83a*

Signature: On the back plate and repeated on the dust cover 'Josiah Emery Charing Cross, London, 1089'. Across the centre of the dial 'EMERY LONDON'.

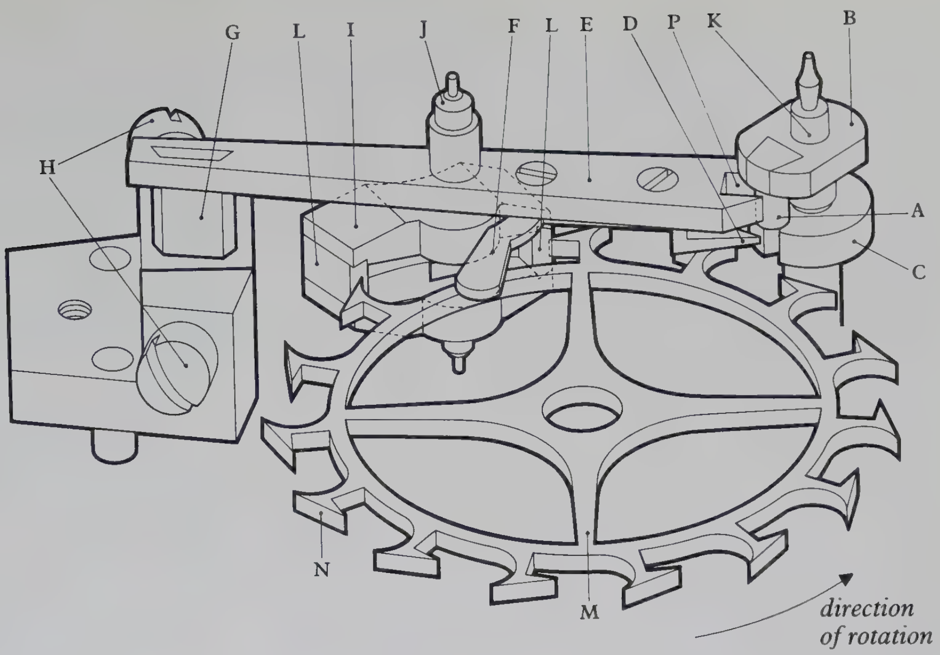


FIGURE 5
John Leroux's lever escapement

A	impulse pin
B	impulse roller
C	safety roller
D	dart
E	lever
F	poising arm
G	banking stone
H	banking screw
I	pallet frame
J	pallet staff
K	balance staff
L	pallet stones
M	escape wheel
N	impulse face of tooth
P	notch

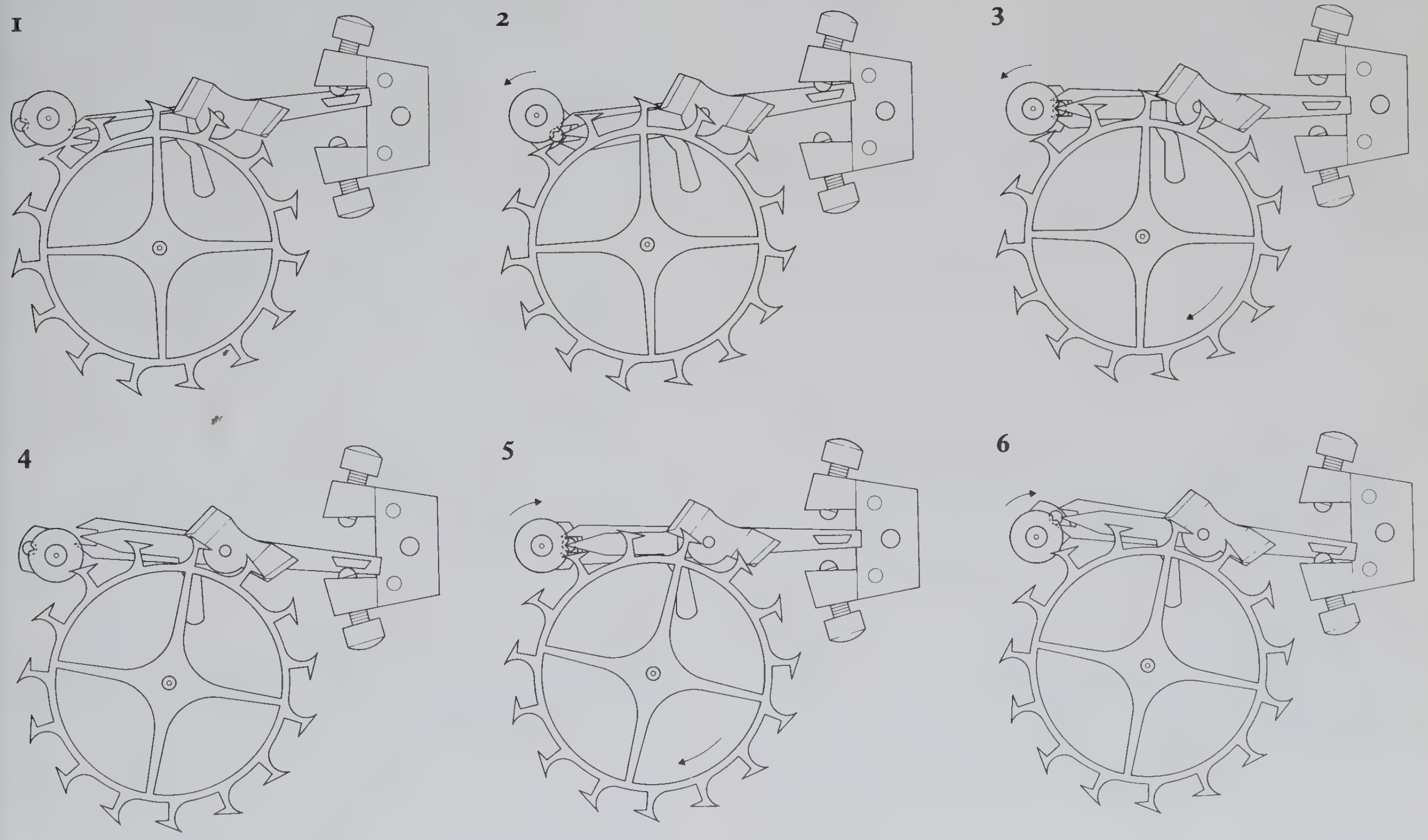


FIGURE 5A
Sequence of operations of John Leroux's lever escapement

1 Escape wheel tooth locked on entry pallet. Banking stone G against banking screw H
2 Impulse pin A entering notch P, tooth about to unlock
3 Wheel has unlocked, pushing lever E via stone L with notch P thus giving impulse to balance via impulse pin A on roller B
4 Escape wheel tooth locked on exit pallet
5 Impulse pin beginning to unlock escape wheel
6 Escape wheel tooth pushing on corner of exit pallet stone L, impulse being given to balance via impulse pin

N.B. Lever cannot move aside at wrong time since dart D can pass safety roller C only when its notch is presented, at correct time for impulse stone to be in notch

Case: Gold consular case with the London hallmark for 1786, the maker's mark V.W., (possibly Valentine Walker) and a duty mark. No case springs, the seven-knuckle book hinge combined for both front and back, chased stirrup pendant. The dust cover fixed bayonet fashion to pieces on the inside of the case. The back centre has chased medallion with a crest almost erased. Diam. 55·8 mm, h. over the glass 25·0 mm.

Dial and hands: The flat enamel regulator style dial retained by two dog screws set in the ends of the feet.

The hands of blued steel, the minute hand in the centre with hour hand above and seconds below.

Movement
Dial plate diam. 45·9 mm; front plate diam. 40·4 mm; back plate diam. 40·5 mm; frame h. between 9·92–10·0 mm.

Frame: Similar to cat. nos 2 and 9. The dial plate held by three screws under the dial, and the movement retained in its case by three dog screws in the dial plate. The front plate is pierced by an almost square hole to admit the lower escape wheel bearing in a cast bridge potance screwed to the underside of the back plate. The two rectangular slots diametrically opposite each other in the edge of the front plate are for the dial feet.

Fusee: Similar to cat. no. 9. The maintaining detent spring lodged partly under the great wheel. The setting-up return spring and tail made from a single piece of steel (c.f. cat. no. 9). The barrel flanged at the cover end and reduced at the other to clear the great wheel. Setting up by means of a square male key which fits a squared hole in the end of the barrel arbor on the front plate end.

Going train: All the brass wheels including the great wheel gilded, the steel pinions and arbors finished to a very high degree. The great wheel has 62 teeth and the train the unusual number of beats per hour of 18,360.

Jewelling: All the pivots of the going train arbors, with the exception of the centre pivot in the back plate and the fusee arbor pivot in the front plate, in pierced jewel bearings. The flat jewels with oil reservoirs set in burnished brass rings, themselves set in recessed holes and retained by polished screws. The pivots of the escapement and balance staff in pierced jewels with endstones similarly set and fixed.

Escapement: In line lever escapement, without draw, with the lift on the pallets, planted between the back plate and a separate bridge screwed and steady pinned to the underside of the back plate (see figs 6 and 6a). The banking pins set eccentrically in brass plugs set flush in the back plate and with screwdriver slots on their upper sides. These have been gilded over, presumably after adjustment at the ébauche stage and not intended to be altered later. The runs to banking very small, and drops just sufficient to clear the tooth tips. The two halves on the impulse roller on different levels can be rotated relative to each other to adjust precisely the shake in the fork, which is somewhat similar to Mudge's fork and roller action.

Balance: Gilded brass flat four-armed balance held on a flange on the balance staff by two screws. Two gold timing screws in brackets riveted to the balance rim and held with clamp screws. The thermal compensation, similar to John Arnold's 'double S' system, mounted on a separate blued steel frame screwed to opposite arms of the balance. Each of the flat S-shaped bimetallic units is made of two separate U-shaped sections riveted together, and fixed to the steel frame with a screw. The hollow gold compensation screws fit onto steel studs on the free ends of the S-units.[1] Diam. 23·1 mm, h. 2·1 mm.

Balance spring: Blued steel helical spring of which about $7\frac{2}{5}$ turns are used, without terminal curves. The lower end of the spring is clamped to an oval brass collet, the upper end to an adjustable overhanging stud. A flanged screw set in the foot, the flange in a groove in the back plate enables the stud to be advanced towards or away from the balance between four short positioning pins standing on the back plate.

Balance stop: Operated by a short lever on the front plate carried on an arbor pivotting in the frame. On the end of the arbor against the back plate is screwed a right-angled arm. The free end of this arm is wedge-shaped and acts on a polished steel spring screwed to the underside of the back plate and carrying a stud in a hole in the back plate. The hole is positioned under the rim of the balance on which the stud acts.

Dust cover: Made in two parts, a deep-sided drum with one end open, the other raised and engraved over the balance cock, and with three holes drilled in it: one for the dust tube around the winding square, the other two for pegs on the back plate of the watch to prevent the drum from turning. The other part of the dust cover is a moulded ring adjusted to turn free through a short angle on the drum. it carries the bayonet fixing to retain the cover on pegs set in the edge of the case.

Going-train counts:
Great wheel (fusee) 62 teeth
Centre pinion 16 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 68 teeth, 6 arms
Escape pinion 8 leaves, wheel 18 teeth, 4 arms
Beats per hour: 18,360

Motion work: (See cat. no. 2)
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Provenance: Duke of Sussex; sold by Christie's on 4 July 1843, lot 49. Ilbert collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1645).

Note
1. There is a reference in Rees's *Cyclopaedia*, 1819–20, p. 18, to the fact that the workmen employed by John Arnold making 'S' balances had left and gone to work for Emery. Arnold started to use the 'S' balance in about 1779 and continued until 1782 during which time, according to Rees, about 40 were produced. Emery's earliest use of the 'double S' balance appears to be about 1782, confirming Rees's statement.

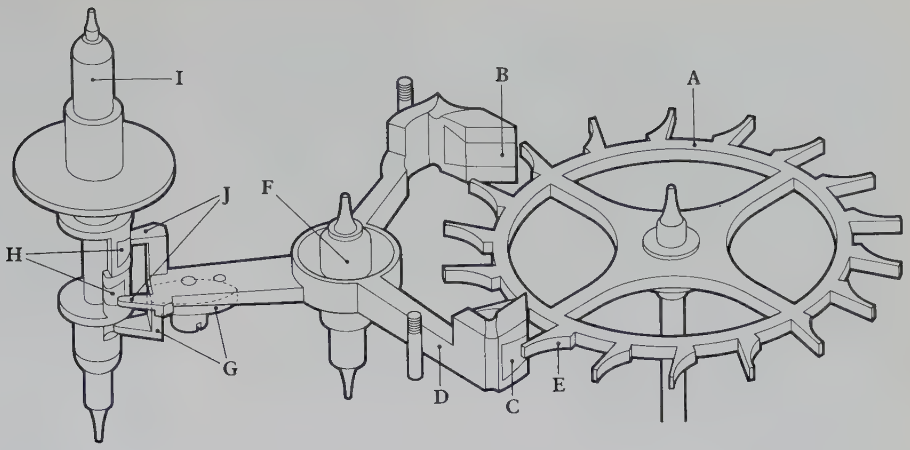
120 ROBERT ROBIN (1742–1799)

EARLY LEVER (MUDGE TYPE) *Plate 83b–f*

Signature: On the back plate 'Robin H^{ger} du Roy a Paris No 370'. On the dial 'Robin H du Roy a Paris'. On the engraved edge of the dial ring 'ROBIN AU LOUVRE'.[1]

FIGURE 6
Josiah Emery's lever escapement

A	escape wheel
B	exit pallet
C	entrance pallet
D	lever
E	escape wheel tooth locked on C
F	pallet staff
G	dart
H	impulse jewels
I	balance staff
J	notch
K1 and K2	banking pins



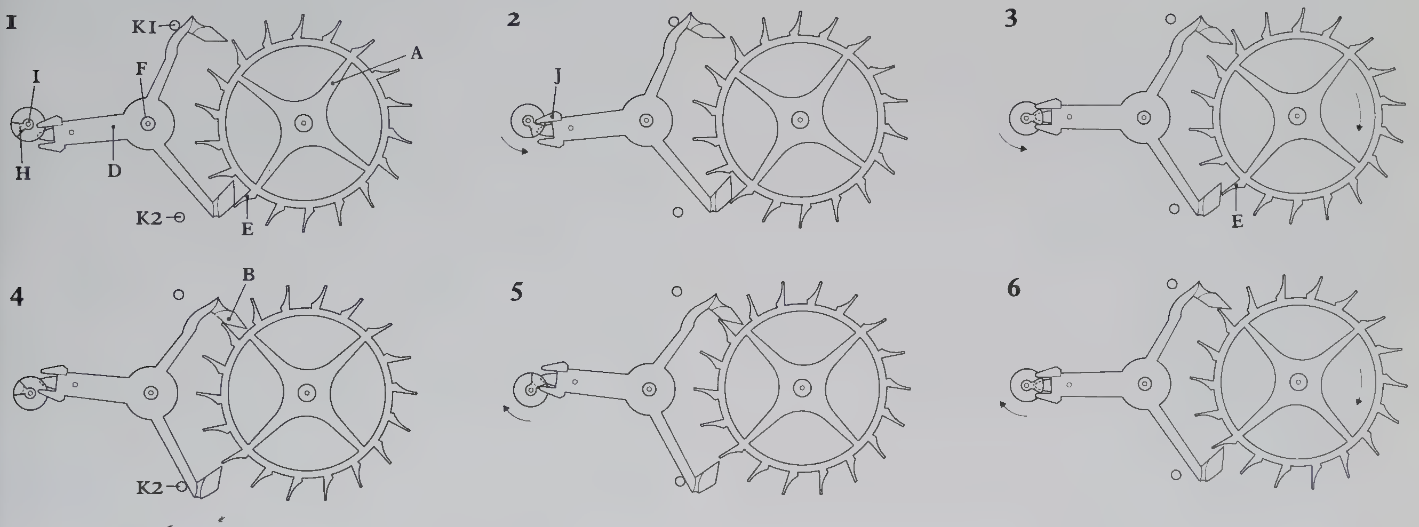


FIGURE 6A
Sequence of operations of Josiah Emery's lever escapement

1. Tooth E of escape wheel A locked on entrance pallet C. Lever D resting against banking pin K1
2. Unlocking about to occur, as impulse stone H enters notch J and begins to rotate lever D clockwise
3. Wheel A rotating as unlocked tooth E is giving impulse to pallet stone C. Lever notch J pushing on impulse stone H thus giving impulse to balance
4. Impulse complete, tooth of escape wheel now locked on exit pallet B. Lever resting against banking pin K2
5. Unlocking about to occur as balance rotates in other direction
6. Tooth giving impulse to balance via exit pallet B

Dial and hands: Flat enamel dial with subsidiary seconds and winding hole, signed on the reverse 'Lucard'[2] (see cat. nos 10, 11, 121, 169). Two cylindrical copper feet with gilded ends pass through the dial plate and front plate, and the dial is retained by pins. The copper edge of the dial also gilded.

Blued steel moon hands. Seconds hand missing.

Movement
Dial plate diam. 56·6 mm; front plate diam. 49·7 mm; back plate diam. 48·3 mm; frame h. 8·7 mm. A cock on the plate for the third and fourth pivots.

Frame: Full plate construction with four turned pillars and pins. The dial ring retained by three screws under the dial and with a positioning peg, and carrying the movement hinge and case catch. The brass parts gilded. The balance top pivots supported by an engraved bridge.

Fusee: Keywind fusee, with a barrel flanged at the cover end and relieved at the other end to clear the great wheel, with stop-work and Harrison's maintaining power made on the English plan. The maintaining ratchet wheel of steel. The polished steel setting-up-work fitted under the dial, the barrel arbor with an extended square for winding on that end only. The mainspring is signed 'Vincent Juillet 1824'. Top pivot of fusee and barrel in engraved cocks.

Going train: The pinions and arbors well polished, the brass wheels polished but not gilded.

Jewelling: Only the pivots of the balance staff in pierced jewels with endstones. The large ruby endstone in a polished steel collet secured by two screws.

Escapement: A development of Mudge's and Emery's lever escapments. The thin brass escape wheel teeth locking very deeply on the radial locking surfaces of the pallets, and with club tooth form giving divided lift. There is no draw. The teeth are not slotted or drilled to retain oil, and no part of the escapement is jewelled. The pallet frame, screwed to its arbor, is pivoted between the back plate and a separate potance. It is made of steel, well finished and polished, and shows almost no sign of wear. Impulse to the balance is transmitted by a gold fork screwed to the end of the lever, which intersects a projection on the balance staff like a single pinion leaf. Below this a brass notched roller provides safety action with the pointed end of the lever. The sides of the lever are banked against two pins set in the back plate. The whole construction is remarkably light and strong, and probably worked very well.

Escapement centre distances: escape–pallets 6·38 mm; pallets–balance 4·69 mm.

Balance and spring: Plain polished steel three-armed balance. Blued steel helical balance spring of 6½ turns, with short incurved ends, the one to the collet slightly the longer. The upper end of the spring pinned to a small blued steel stud, itself screwed to an overhanging engraved brass piece screwed and pinned to the back plate. There is no sign of any thermal compensation except for three short steel pins set in the balance rim and projecting inwards. The balance has been poised by filing the underside of the rim. The index registers against a scale on the back plate.

Going-train counts:
Great wheel (fusee) 66 teeth
Centre pinion 12 leaves, wheel 64 teeth, 4 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 60 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 15,428·571

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

The cannon pinion snapped on as in modern practice.

Provenance: Ilbert Collection; purchased by Ilbert from 'President' in 1938 (reg. no. CAI-1153).

Notes

1. A very similar watch to this signed, *Robin a Paris No 59*, has the addition of a thermal compensation device acting on the index. The compensating device is lodged under a circular bridge running round the back plate and just inside the edge. On this is engraved the inscription 'Compensation inventee par Robin H aux Galeries 1789'. Robin died in 1799 and it is assumed that any watch made by him and engraved 'Horloger du Roi' must have been made before 1792. If so, then this watch, 'No 370', must have been made between 1789 and 1792. Chamberlain 1941 mentions a pamphlet published by the Rev. Nevil Maskelyne, Astronomer Royal in 1792, in which Maskelyne states that Josiah Emery had made and supplied two of his watches with lever escapements to the King of France, and that Robin had made a watch using these as models.

2. Lucard is known to have been working 1806–20.

121 ROBERT ROBIN (1742–1799)

WATCH MOVEMENT *Plate 84a–d*

Signature: On the back plate 'Robin A PARIS No. 558'. On the dial below 6 'ROBIN H$^{\underline{\text{GER}}}$ DU ROI'. On the dial plate edge 'ROBIN H$^{\text{R}}$. DU ROI'.

Dial and hands: Domed white enamel dial, arabic hour numerals, no seconds indication, signed on the reverse 'Lucard' (see cat. nos 10, 11, 120, 169).

Later blued steel moon hour hand, the minute hand missing.

Movement

Dial ring diam. 52·3 mm; Front plate diam. 49·3 mm; Back plate diam. 46·5 mm; Frame h. 13 mm.

Frame: Full plate construction with four turned pillars and pins. A separate dial ring is secured to the front plate by three dog screws, it has an engraved edge. The movement hinge and case catch are secured to the front plate. All the brass parts are finely gilded.

Fusee: With English-type stop-work, well finished and polished, and Harrison's maintaining power with a steel ratchet wheel. The barrel has a wide flange at the cover end. The setting-up-work is mounted on the back plate.

Going train: Conventional, the brass wheels polished, the pinions with thin round topped leaves and correspondingly wide spaces. The fourth pinion not original.

Escapement: Lever escapement similar to cat. no. 120. The thin brass escape wheel teeth locking deeply on the radial locking surfaces of the pallets, the club-tooth form giving divided lift. The working surfaces of the pallets and steel impulse pin showing signs of considerable wear. The teeth are not slotted or drilled to retain oil, and no part of the escapement is jewelled. The fork and roller action similar to cat. no. 120 except that the fork is made of nickel, and perhaps is a later replacement. The pallet frame is threaded onto its staff. Two holes have been drilled in the back plate for the upper pallet staff pivot on the centre line of the escapement, the one nearer the balance is the one used. There is also a long rectangular slot in the back plate radiating from the balance centre, as if for an Arnold detent.

Escapement centre distances: escape–pallets 6·38 mm; pallets–balance 4·69 mm.

Balance and spring: Plain brass three-armed balance made very light, with a flat spiral spring of blued steel on the underside, of just over 6 full turns. The balance spring pinned to a block on the back plate, and having a Tompion type of regulator. No sign of any kind of thermal compensation. Diam. 21·3 mm, h. 0·5 mm.

Repeating work: Continental-type quarter repeating work operated by depressing the case pendant. There is a regulator on the back plate to alter the speed of running of the repeating train by varying the free movement of the anchor pallets.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 10 leaves, wheel 70 teeth, 4 arms
Third pinion 7 leaves, wheel 56 teeth, 4 arms
Fourth pinion 7 leaves, wheel 60 teeth, 4 arms

Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Repeating-train counts:
Great (first) wheel 42 teeth
Second wheel 36 teeth, pinion 7 leaves
Third wheel 30 teeth, pinion 7 leaves
Escape wheel 10 teeth, pinion 7 leaves

Motion work:
Cannon pinion 12 leaves, minute pinion 12 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Contarde in 1938 (reg. no. CAI-1154).

Note: Cedric Jagger described a remarkably similar watch in A.H.S., Vol. V, December 1965. The only important differences is that the escapement, instead of being in line, has the wheel to pallet centre line at right angles to the balance to pallet centre line. This watch is signed 'Robin no 3' and bears inscriptions from which the date of manufacture can reasonably be assessed as 1792. Around the edge of the engraved dial ring appears the incomplete inscription 'Robin H^{R}du -'. The word 'ROI' is missed out and the 'du' is incomplete. The dial is signed 'ROBIN DE LA SOC.^{TE} DES INV.^{TONS} et DECOUVERTS'. According to the Conservatoire des Arts et Métiers, Paris, this Society existed for only a few months in 1792.

Robert Robin was born in 1742 and received the royal appointment to Louis XV and Louis XVI. In 1793 he tried to leave Paris, but having no passport was caught and imprisoned with Antide Janvier at Saint-Pélagie. He later made clocks with decimal indications and, according to Tardy, was cited as 'horloger du Directoire' in 1795 (year VI of the Revolutionary Calendar).

See also the following watches in the collection:

1. François-Louis Godon, Mudge/Emery lever (reg. no. CAI-1178).
2. Sirost No/1803, Mudge/Emery lever (reg. no. CAI-1097).
3. Louis Berthoud No 2546, pin wheel lever (reg. no. CAI-1182).
4. J. G. Remond & Co. a Geneve, pin wheel lever (reg. no. CAI-1137).

These four are all early levers for non-precision application, and as such are not included in this catalogue.

122 A. L. BREGUET

Started 2 August 1791, sold to Gide
12 September 1791.

PEDOMETER WOUND LEVER WATCH – 'PERPETUELLE' *Plates 84e–f, 85a–f, 86a*

Signature: Around the edge of the movement: 'Inventé par Breguet à Paris No 46 Quai de l'Horloge No 65'.

Between No and 46, the small letters H.S.

Case: Red gold case, the middle and back decorated with fine engine-turning. Pump pendant to operate the quarter repeating work retained by a steel plate and four screws inside the case. The banking springs for the pedometer weight also fixed inside the band of the case. Only the front of the case opening, the back fixed, no inner dome or cuvette. A roller on the pedometer weight bears against the back of the case. The only mark inside the case 65 over B. Diam. 50·8 mm, h. 18·4 mm.

Dial and hands: Silver engine-turned dial with subsidiary seconds and up-and-down indicator.

Blued steel hands.

Movement
Distance piece diam. 48·6 mm; front plate diam. 46·3 mm; back plate diam. 43·6 mm; frame h. 5·1 mm.

Frame: Similar to cat. no. 123.

Pedometer wind: There is no provision for winding the two mainsprings except by the pedometer mechanism. The solid platinum weight winds the two mainsprings simultaneously through a reduction gear.

Two large wheels, one with damaged teeth, are mounted one on each going barrel arbor. The pedometer weight is on a squared arbor on which is also a steel ratchet wheel with fine teeth. This wheel is fitted into a recess in a larger brass wheel having fine ratchet teeth on its edge. In the recess in the brass wheel are also two steel clicks and return springs acting on the steel ratchet wheel. Two more steel clicks carried on posts set in the front plate act on the ratchet teeth on the edge of the brass wheel. When the pedometer weight moves down, as a result of the movement of the wearer of the watch, both ratchet wheels turn and the mainsprings are wound. When the weight moves up only the fine toothed steel ratchet wheel moves past its clicks, the brass wheel remains stationary. A coiled spring is provided, with means for setting it up to the correct tension, to keep the pedometer weight in about the middle of its travel when the watch is held still with the pendant up.

The pedometer weight does not normally touch either the back plate or the inside of the back of the case. However a pivoted steel roller on the outside of the weight, and a polished steel screw on the back plate prevent the weight from rubbing on the back of the case or back plate, if the weight should be thrown against either. This refinement is absent in cat. no. 123.

Up-and-down movement of the pedometer weight is limited by two springs inside the band of the case. Cat. no. 123 has only one of these.

Stop-work: Similar to cat. no. 123. In neither watch is there any provision for setting up the mainsprings.

Up-and-down work: Similar to cat. no. 123.

Going train: Similar to cat. no. 123. The reserve of going is also some sixty hours, the counts of the trains are different, the gilding and general finish better than that of cat. no. 123.

Jewelling: Similar to cat. no. 123 except that the impulse pin is not jewelled.

Escapement: Similar to cat. no. 123 except that the escape wheel has more and finer teeth. One tooth is broken off and another badly damaged.

Balance: Gold three-armed balance lodged under the dial on the front plate. Diam. 15·2 mm, h. 0·6 mm.

Balance spring: Blued steel spiral spring without terminal curve, the last turn taken out well clear of the rest to work with the regulator, and pinned to a block on the front plate outside the balance.

Thermal compensation: This is combined with the regulator. The regulator lever is pivoted in a frame lodged between the plates. One end carries the index pins, the other has a slot for a pin, at the free end of the double bimetallic strip approximately concentric with the balance. The other end of the bimetallic strip is fixed to a carriage by an adjustable block to alter the amount of compensation. If the bimetallic strip is moved towards the balance centre its effect will be increased and vice-versa. The carriage has an integral toothed sector, gearing with a toothed wheel pivoting on a shoulder screw. This wheel has a piece cut out and acts as a stop with a peg in the front plate. The worm meshing with the teeth of this wheel has a short square section on the end passing through the distance piece on the edge of the movement. By turning this with a key, the watch can be brought to time. The bimetallic strip also causes the index to move with changes in temperature.

Repeating work: Similar to cat. no. 123, but a spring for the all-or-nothing work has been removed. Other differences are only those of detail.

Going-train counts:
Great wheels (barrels) 90 teeth each
Intermediate pinion 10 leaves, wheel 35 teeth, 4 arms
Centre pinion 18 leaves, wheel 64 teeth, 4 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 60 teeth, 4 arms
Escape pinion 8 leaves, wheel 20 teeth, 4 arms
Beats per hour: 18,000

Repeating train: Four pinions of seven leaves, the fly of eight leaves. The wheels of 58, 36, 34, 31 and 29 teeth respectively.

Motion work:
Cannon pinion 10 leaves, minute pinion 8 leaves
Hour wheel 32 teeth, minute wheel 30 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Desoutter in 1934 (reg. no. CAI-3132).

Exhibited: Musée International d'Horlogerie, La Chaux-de-Fonds, Switzerland, May–September 1976; see exh. cat., pp. 24, 25.

123 A. L. BREGUET

Started March 1789, sold about 1792.

PEDOMETER WOUND LEVER WATCH – 'PERPETUELLE' *Plates 86b–e, 87a–c*

Signature: Around the edge of the movement 'No 27 Inventé par Breguet à Paris'.

Case: Red gold case, the middle and back decorated with fine engine-turning, with a pump pendant to operate the quarter repeating work. The middle a thin band carrying the hinges for the front and back, no inner dome or cuvette. The back made from a disc snapped into a narrow rim. The front a narrow rim into which the glass is snapped. No case maker's or other marks. Diam. 48·8 mm, overall h. 17·3 mm.

Dial and hands: Slightly curved enamel dial, with subsidiary seconds and up-and-down indicator, signed on the back 'Noirmont'.

Blued steel hands, the minute and seconds hands not original.

Movement

Distance piece (see below) diam. 43·8 mm; front plate diam. 41·0 mm; back plate diam. 39·6 mm; Frame h. approx 9 mm.

Frame: Full plate construction with five turned pillars, the back plate secured by screws. Between the dial and the front plate a brass ring or distance piece retained by four dog screws in the front plate, to leave room for the repeating and other work. The dial held by two short flat feet, and screws going through the edge of the distance piece. The back plate pierced with holes for the escapement, the winding work and the mainspring barrels. There are also a number of holes in the plates to enable the gearing to be checked.

Pedometer wind: A lead-filled platinum weight pivoted at the edge of the movement winds two mainsprings simultaneously through a reduction gear. The two large wheels are adjusted one on each going barrel arbor, the squared arbor carries the pedometer weight. The squared arbor is part of a five-toothed ratchet wheel set inside a larger five-toothed brass ratchet wheel. When the pedometer weight moves down both ratchet wheels turn and the main springs are wound. When the weight moves up only the five-toothed steel ratchet wheel turns, the other five-toothed wheel is held by a pair of clicks (see the description of cat. no. 122).

Stop work: The barrel furtherest from the pendant carries a form of Geneva stop-work on the cover end. The barrel arbor is allowed to turn during winding for a maximum of three turns relative to the barrel. A raised part of the stop-piece then contacts a spring lever and applies the catch to hold up the pedometer weight.

Up-and-down indicator: The barrel nearer the pendant has an extended threaded arbor on the cover end, on which runs a threaded steel disc with four slots. A peg set in the barrel cover passes through one of the slots and prevents the disc from turning. However when the barrel turns during running, or the arbor during winding, the steel disc moves up or down the threaded arbor. The disc moves away from the barrel during winding and towards it during running. A pivoted arm has one end in contact with the top of the disc and the other in contact with a spring-loaded cam on the arbor carrying the indicator hand.

Going train: There is an intermediate wheel between the two going barrels and the centre pinion. The going train wheels have wide rims but fine teeth. The gilding is of poor quality. When fully wound the watch has a maximum reserve of going of some sixty hours.

Jewelling: The cone-shaped balance pivots run in blind holes in small discs of ruby set in springy steel arms. This is an early example of Breguet's elastic or parachute suspension to protect the balance pivots if the watch receives an external shock.

The pivots are actually held without endshake between the elastic suspension at each end of the balance staff. Stop-pieces are provided to limit the possible axial movement of each suspension.

The steel pallets and impulse pin are provided with inset jewels.

Escapement: In line lever escapement with all the lift on the pallets, the locking surfaces radial and so without draw. The teeth of the brass escape wheel very thin and delicate, and further weakened by slotting for oil retention.

The fork and roller action similar to a Savage two-pin arrangement. Two gold pins set in the heart-shaped end of the fork, contact a jewelled wedge-shaped impulse pallet. Banking for the lever is effected by a slot in the counterpoise fork tail acting against the escape arbor. Safety action provided by a small gold roller with passing hollow, and the pointed end of the heart-shaped fork.

Balance: Four-armed brass balance with bimetallic strips secured to the ends of the two of the arms. A similar arrangement to John Arnold's 'z' balance but much lighter. There is a good deal of evidence to suggest that the balance is a later replacement for an arrangement similar to that in cat. no. 122.

Balance spring: Blued steel spiral spring without terminal curve, the regulator operated by turning a squared arbor in the edge of the movement with the key. The regulator arbor has been repositioned relative to the original arrangement. On turning the squared arbor a block moves along the threaded portion. Concentric with the balance spring and below it is a brass ring carrying the index pins. An arm on the outside of this ring carries a pin passing into a slot in the block; as soon as the block moves the ring, and thus the index pins, move with it.

Repeating work: On depressing the pendant the repeating mainspring is wound by a chain passing onto a pulley on its arbor. The hours are sounded by teeth on a steel three-armed wheel carried on the repeating mainspring arbor and the quarters by further teeth on this wheel, all acting on a single hammer. All-or-nothing work is incorporated acting on the lifting piece on the hammer arbor.

The number of hour blows repeated is controlled by a cam on a star wheel indexed at each hour by a piece on the cannon pinion. This part of the mechanism operates in the usual way for watch repeating work. The number of quarters repeated is controlled by the cam on the cannon pinion and the rack with three teeth. This rack is gathered by a block on the pivoted steel plate to which the end of the winding chain is attached. One of the three teeth touches the lifting piece in its path and moves the hammer lifting piece out of the path of the teeth on the steel three-armed wheel.

There is no gong or bell for the repeating hammer to strike, it hits a block on the side of the case and thus performs what is called dumb repeating.

Going-train counts:
Great wheels (barrels) 66 teeth each
Intermediate pinion 12 leaves, wheel 36 teeth, 4 arms
Centre pinion 12 leaves, wheel 60 teeth, 4 arms
Third pinion 8 leaves, wheel 64 teeth, 4 arms
Fourth pinion 8 leaves, wheel 60 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Repeating train
All the pinions of 6 except the fly pinion of 8 leaves.
The first wheel, on the barrel arbor, 48 teeth, the remainder 32, 30, 26, and 21 teeth respectively.

Motion work:
Cannon pinion 10 leaves, minute pinion 8 leaves
Hour wheel 32 teeth, minute wheel 30 teeth.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1935 (reg. no. CAI-275).

124 JOSIAH EMERY

c. 1794 (No. 1289 is 1792)[1]

Plates 87d–e, 88a–d

Signature: 'Josiah Emery Charing Croſs London 1379'. On the dial below XII 'EMERY LONDON'.

Case: Later silver case without hallmarks apparently made especially for the movement. The glazed bezel is hinged to the middle at the front, the cuvette and back hinged to the middle almost opposite the pendant. Pump pendant to operate the repeating work. Diam. 59·7 mm, h. over glass 26·7 mm.

Dial and hands: Enamel dial with blue figures, the centre of the subsidiary seconds dial sunk.

Gilded brass minute and hour hands, blued steel seconds hand.

Movement
Dial plate diam. 53·3 mm; front plate diam. 47·7 mm; back plate diam. 45·1 mm; frame h. 9·8 mm.

Frame: Full plate construction with five turned pillars, the back plate retained by pins. The edge of the dial plate engraved, and attached to the front plate by three screws under the dial. The dial with two feet secured by screws in the edge of the dial plate. No case catch or hinge or any provision for them. The movement secured in its case by three dog screws on the back plate. No dust cover fitted to the movement. All the brass parts gilded except fourth cock on the front plate under the dial. On the dial plate under the dial the scratched inscription: 'R. Rippon fecit London 1795'[2] as well as repairers' scratched marks, 'Cleaned by T. Lawson Brighton 1831 and 1835 and G. Jamison, Portsmouth'.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass. The polished maintaining detent fitted free to turn on the arbor of the stop/start lever, and returned by a spring lodged under the great wheel acting on a steel pin set in the detent. The barrel arbor squared at both ends, the one-piece setting-up ratchet click and return spring, and setting-up ratchet wheel, mounted under the barrel on the front plate. The ratchet wheel squared onto the barrel arbor and with a short pipe passing into a hole on the front plate.

Going train: The third and fourth wheels each have four arms instead of six as is more usual with Emery lever watches.

Jewelling: On the back plate, the fusee, third and fourth arbor pivots run in pierced jewels and the escapement arbors in pierced jewels with endstones. On the front plate the centre, third and fourth arbor pivots run in pierced jewels, and the escapement arbors in pierced jewels with endstones. The balance staff pivots run in pierced jewels with endstones, the endstone in the balance cock a diamond set in a polished steel ring.

Escapement: In line lever escapement with all the lift on the pallets. The steel escape wheel polished all over, the teeth slotted to retain oil. The steel pallet frame also polished all over, with jewelled pallets and gold dart. There is no draw on either pallet. The impulse roller on the balance staff carrying a pivoted steel roller, the roller pivoted in jewel holes. The passing hollow for the dart scooped out of the material of the balance staff. The escape wheel pivoted in the frame, the pallet frame pivoted in an extension of the balance potance and a disc set in the back plate and secured by four marked steel screws. Compare with the similar escapement fitted in cat. no. 119; in the earlier version the teeth of the escape wheel are not slotted and the impulse roller differs.

Balance: Built up on a gilded brass four-armed wheel secured by two screws to a polished steel collet on the balance staff. Two 's'-shaped bimetallic strips carrying gold compensation screws are attached to a steel bracket, itself screwed to the balance wheel. Two other gold screws for bringing the watch to the time pass into brackets on the rim provided with clamping screws. Each of the four compensation and timing screws is made up of a gold head on a steel thread. Diam. 24·1 mm, h. 2·0 mm.

Balance stop: Operated by a lever projecting from the edge of the dial plate, and exposed when the front bezel is opened. On moving the lever to one of two positions controlled by a stiff jumper spring, an arbor pivoted in the frame is turned through a small angle in one or other direction. This arbor carries an arm with an inclined plane acting on another springy arm screwed to the underside of the back plate. A block fixed to the free end of this intercepts or clears the underside of the balance rim. The maintaining detent is also carried on the arbor pivoting in the frame. All this steel mechanism is well and carefully made, almost all the surfaces being very highly polished.

Balance spring: Blued steel helical spring of about $7\frac{1}{3}$ turns without terminal curves. The brass collet with clamping device for the lower end of the spring. The upper end clamped to the gilded brass overhanging stud with adjustment towards or away from the balance centre, similar to cat. no. 119.

Going-train counts:
Great wheel (fusee) 65 teeth
Centre pinion 16 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 72 teeth, 4 arms
Fourth pinion 9 leaves, wheel 58 teeth, 4 arms
Escape pinion 7 leaves, wheel 18 teeth, 4 arms
Beats per hour: $17{,}897\frac{1}{7}$

Motion work:
Cannon pinion 4 pins, minute pinion (brass wheel) 32 teeth
Hour wheel 32 teeth, minute wheel 48 teeth

Repeating work:
First wheel 42 teeth
Second wheel 37 teeth, pinion 6 leaves
Third wheel 33 teeth, pinion 6 leaves
Fourth wheel 30 teeth, pinion 6 leaves
Fifth wheel 25 teeth, pinion 6 leaves
Sixth pinion 6 leaves

Half-ten-minute repeating mechanism: Basically a Stogden type of mechanism, repeating the hours on one gong, the number of ten-minute intervals after the hour on two gongs, followed by an extra blow on the higher pitched gong if more than five minutes towards the next interval. The train and both hammers pivoted between the plates of the frame, all the lifting work and other mechanism fitted on the front plate under the dial. The repeating mainspring wound by rack and pinion rather than by chain and pulley. The hour cam carried on the minute wheel concentric with a steel star wheel. All-or-nothing device fitted to prevent the mechanism from repeating any blows unless the operating plunger in the pendant is pushed fully home. All the steel parts very well finished, their upper surfaces polished.

Provenance: Ilbert Collection; purchased by Ilbert from Webster in 1930 (reg. no. CAI-510).

Notes

1. No. 1289 is in the collection of the Worshipful Company of Clockmakers.
2. Baillie 1951 states that a Richard Rippon working at the Seven Dials, King Street, London, between 1810 and 1824 was a maker of repeating mechanisms and teacher of E. J. Dent. Dent married Rippon's widow.

Bibliography: Chamberlain 1941, p. 118, refers to the roller pivots in jewels.

125 JAMES BULLOCK
c. 1794

MARINE CHRONOMETER WITH LEVER ESCAPEMENT
Plates 88e, 89a–b

Signature: On the dial only 'James Bullock London.'[1]

Box: The movement contained in a wooden drum, brass bound at the top, with a hinged brass bezel and domed glass. The dial plate fits flush in a shallow rebate, positioned by brass pieces projecting into slots in the edge. A painted plaster weight to level the drum is screwed to the underneath. The drum is gimballed in a plain baize-lined mahogany box without a glazed panel in the top. There is an ivory escutcheon plate over the lock, an ivory disc inset in the front of the top and a brass one in the centre of the lid. The gimbal ring, numbered *217*, can be locked by a brass rod passing through a bracket, a hole in the ring and into a hole in a brass piece screwed to the wooden drum. This rod has a knurled knob and is threaded in the bracket. Wooden drum diam. 120 mm, h. 101·5 mm over glass. Box 196·5 mm square, h. 187 mm.

Dial and hands: Engraved, silvered, brass dial of regulator type, secured by four feet and pins to the dial plate. The engraving filled with black wax. There is a hole for winding.

Movement
Dial plate diam. 109 mm; front plate diam. 100·6 mm; back plate diam. 100·5 mm; frame h. 27·6 mm.

Frame: Full plate construction with four turned pillars, the back plate secured by pins. The wide balance cock is set in from the edge of the back plate, the balance staff passing through the frame to a cock on the outside of the front plate. There are two almost diametrically opposite brass blocks screwed and pinned to the back plate, with no apparent function. The dial plate is held clear of the front plate and fixed by three pillars and pins. It is marked out for the dial on the underside and faintly scratched 1794.

Fusee: Winding from the front and with the usual stop-work and maintaining power. The maintaining detent is held against the ratchet wheel by a piece of brass wire set in the back plate and pointing down. The block for the stop piece has a squared portion passing through the back plate and secured by a pin. The fusee is made as in clockwork with a single winding click, and the great wheel held by a brass plate and screw. The mainspring is straight grained and not blued, and stamped with the figure 3 at the end. It is hooked to the solid, unsnailed barrel arbor and to a hook set in the barrel wall.

Going train: Well made but poorly finished, the wheels, except the fourth, riveted to their pinions.

Jewelling: None. On the lower end of the balance staff is a small diameter train pivot running in a plain hole in the brass cock. That at the back resembles an Arnold balance pivot and runs in a brass bush with the end resting on the polished end of a screw set in a steel plate held by two other screws.

Escapement: In line lever escapement with lift on the pallets, the large ratchet-toothed brass wheel riveted on a collet on its pinion and planted in the frame. The massive steel lever and pallets with integral upstanding pads, screwed to a collet on an arbor pivoted between the back plate and a potance screwed and pinned to the front plate. The back plate bearings for both escape pinion and pallet arbors are in separate detachable plates with wedge-shaped steel endpieces dovetailed in place. The fork works with a roller on the balance staff pivoted between demountable brass shrouds. Safety action is provided by a long brass dart riveted to a collet on the pallet arbor, and a brass roller on the balance staff. Banking for the fork consists of a wide slot in a brass strip bent down at right angles and screwed to the back plate at the edge of the hole for the balance staff. There is no draw.

Balance: Built up from two crossbars at about 30° to each other, one of steel, the other of brass. Two short brass rim sections are attached with pins in slots in the ends of the crossbars. The ends of the brass crossbar are attached at the ends of the rim sections; the ends of the steel crossbar nearly mid-way along the rim sections. The free ends of the rim sections are threaded for steel screws with brass knurled heads.

The steel cross-bar is riveted to a brass collet on the balance staff, the brass one is sandwiched between the steel crossbar and the brass balance spring collet fixed with a clamping screw. Diam. of rim 25·6 mm, h. 2·9 mm.

The action of the compensation is similar to that for an ordinary bimetallic balance. A rise in temperature will cause a greater expansion of the brass than the steel crossbar. This will result in the free ends of the rim sections moving towards the centre of the balance. Apart from the lack of rigidity of the linkages, it seems unlikely that the movement of the rims would be sufficient to compensate for a carbon steel balance spring. One would have expected to find a series of holes in each rim section so that the pinning point of the steel crossbar could have been moved towards or away from that of the brass one to alter the compensation. However there are no signs of any such holes.

Balance spring: Blued steel conical spring of three turns, without terminal curves, pinned in a square hole in a brass collet on the edge of the balance cock. The spring is pinned in a similar square hole in the collet. There is an index with provision for clamping the tail, on the balance cock. This reduces the acting part of the balance spring to 2¾ turns.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 12 leaves, wheel 64 teeth, 4 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 64 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1934). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Exhibited: British Clockmakers Heritage, Science Museum, London, May–September, 1952. 'Pendulum to Atom' under the auspices of The Worshipful Company of Clockmakers at Goldsmiths' Hall, London, October, 1958.

Note

1. Baillie 1982 records a James Bullock working in Leather Lane 1776–94 and also at Furnivals Inn Court 1790–4. James Bullock was one of the witnesses to the will of William Dutton.

Bibliography: Bertele 1981, p. 149.

126 RICHARD PENDLETON

c. 1800 (No. 175 is dated 1797)

LEVER WATCH *Plates 89c–e, 90a*

Signature: 'R. Pendleton London N 172'.[1]

Case: Original case missing, now contained in an engine-turned silver box, glazed front and back.

Dial and hands: Flat enamel dial of the regulator type unsigned. Blued steel hands.

Movement
Dial plate diam. 48·8 mm; front plate diam. 47·5 mm; back plate diam. 45·3 mm; frame h. 10·3 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins, without a detachable barrel bridge. The layout and construction show a strong resemblance to the Josiah Emery lever watch, cat. no. 119. The dial fixed to the dial plate by three feet and pins, three dog screws also set in blocks in the dial plate to retain the movement in its case. There is no case catch or hinge. The dial plate fixed to the front plate by three short feet and pins. The escapement is pivoted between the back plate and a massive bridge screwed to the underside of the back plate. There is a rectangular hole in the front plate to clear the escape wheel potance which is now integral with the bridge but which appears once to have been a separate piece.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel brass, the maintaining detent spring partly lodged under the great wheel, both it and the detent highly polished. The stop-piece of the stop-work lodged in an ornately pierced block, similar in every detail to that of cat. no. 119. The setting-up-work lodged under the barrel on the front plate, the barrel arbor squared on the front plate end only. The barrel flanged at the cover end and reduced at the other to clear the great wheel.

Going train: Although the wheel and pinion counts are not identical to any of the watches by Emery, the third and fourth wheels have six arms similar to cat. no. 119 and the two watches were made at a time when it was unusual for these wheels to have six arms, four being more usual and then later five. The finish and polish of the two trains are identical.

Jewelling: The fusee upper pivot, centre arbor lower pivot, and those of the third and fourth arbors run in pierced jewels set in brass rings retained by screws in recessed holes in the frame. The third and fourth arbor jewels have deep oil sinks. The pivots of the escapement arbors run in pierced jewels with endstones, a diamond endstone in the balance cock set in a polished steel ring (see below).

Escapement: Lever escapement with all the lift on the pallets and without draw. The wheel and pallet action similar to that of cat. no. 124, the polished steel escape wheel appears to be very similar to that of cat. no. 124, the teeth are slotted in a similar way, but the dimensions are slightly greater. The pallet frame has two arms with pallets at their ends, the fork being integral with and beside the entry pallet, and with the gold dart screwed on the polished underside. The third integral arm of the pallet frame is a counterpoise and is banked against banking pins set in holes in the back plate. The end of this arm is left thicker than the rest but is still of insufficient weight to poise the frame. Impulse is delivered to the balance via a steel roller pivoted in pierced jewels in a frame on the balance staff, the construction is again similar to that of cat. no. 124. The dart works in conjunction with a roller having a rectangular scooped out hole. From the way in which the escapement of this watch and that of cat. no. 124 are made and finished it is inconceivable that they were not made by the same person or at least in the very closest possible collaboration. Comparing the escapement pivots of this watch with those of the Emery, cat. no. 124, one notices that the escape pinion and pallet arbor pivots are of similar shape, a straight cylindrical working portion joined with a slight shoulder to a straight-sided cone at each end of each arbor. The balance pivots of the two watches are similar, but differ from the escapement pivots in that they are straight-sided cones. The escapement pivots of the other Emery lever in the collection, cat. no. 119, are all of the same shape, and differ from any of the above, in that they are long conical pivots.

There thus seems to be little doubt that the Emery lever watches and the Pendleton watch were made at least by the same team of craftsmen, because although detailed differences exist, the overall style is the same.

Balance: Similar to that of cat. no. 124, but with two additional plain gold screws set in the blocks for the timing screws.

Balance spring: Blued steel helical spring without terminal curves. Overhanging gilded brass stud with a screwed clamp to hold the end of the balance spring. Brass collet with screwed brass piece to hold the lower end of the balance spring similar to that of Emery cat. nos 119 and 124.

Balance stop: A polished steel arbor passing through holes in the edge of the frame has an integral lever on the dial plate end, one end acting on a two position spring, the other protruding from the edge of the watch at what would normally be the 4 o'clock position on the dial. The other end of the arbor projects through the back plate and carries a lever on a squared portion, this lever acts on a springy arm passing under the balance rim to hold up or release the balance. All these steel parts are polished to a high degree.

Balance cock: Overhanging cock engraved all over the upper surfaces with plant, flower and fierce mask motifs.

Going-train counts:
Great wheel (fusee) 62 teeth
Centre pinion 16 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 76 teeth, 6 arms
Escape pinion 9 leaves, wheel 18 teeth, 4 arms
Beats per hour: 18,240

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Ash in 1932 (reg. no. CAI-1118).

Note

1. Richard Pendleton is known to have been working *c.* 1795–1805 as a servant to Emery and he also worked for Mudge jun.

127 JOHN GRANT

c. 1798 (No. 1479 has the hallmark for 1795)

LEVER WATCH MOVEMENT *Plates 90b–e, 91a–c*

Signature: On the back plate and barrel bridge 'GRANT Fleet Street N°. 1736'. On the dial 'GRANT LONDON'.

Dial and hands: Flat enamel dial with intersecting offset minute and hour, and seconds circles, secured by screws in the edge of the dial plate into three wide feet. On the reverse the signature 'Weslon [*sic*]' (see cat. no. 129).[1]

Gold minute and hour, steel seconds hand.

Movement
Dial plate diam. 50·1 mm; front plate diam. 46·5 mm; back plate diam. 45·2 mm; frame h. 8·8 mm.

Frame: Similar to cat. no. 129 but with differences in detail. The back plate secured by screws, two of them also securing the barrel bridge. The dial plate fixed to the front plate by three screws under the dial, accessible only after removal of the dial. The three slots in the edge of the front plate are for the dial feet. A long bridge on the front plate with the lower bearings of the fusee, third and fourth wheel arbors. The case catch spring is planted on the opposite side of the front plate but the catch still works partly under the bridge. The balance cock foot extends to the edge of the back plate. Both cock and barrel bridge engraved with matched engraving.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel brass, the long detent return spring planted with its foot almost touching the case catch. Worm and wheel setting-up-work, a late example of its use. A flange at the top of the barrel.

Going train: The centre arbor offset, the fourth wheel a contrate and the escape pinion of six leaves similar to cat. no. 129, but the great wheel has 63 teeth.

Jewelling: Similar to cat. no. 129. The upper balance endstone a ruby in a blued steel screwed setting.

Escapement: Two-plane lever escapement with two polished steel escape wheels both mounted on the arbor of the escape pinion with their axis at right angles to that of both the lever and balance staff. The escape wheel mounted between two potances both with bearing adjustment for optimum positioning of the wheel. In the fork and roller action the impulse roller on the balance staff is a small ruby tube set on a steel arbor with pivots in a brass frame on the balance staff. Safety action is provided primarily by a dart with a passing hollow cut out of the balance staff and also by short horns on either side of the notch. Banking is provided against screws set in the balance potance.

The pallets consist of a single segment-shaped piece of ruby held on an arm adjusted onto the pallet staff and working between the two wheels in a slot cut out of the back plate. There is no draw, the wheel teeth being locked on the concave inside radius of the piece of ruby. Impulse is given against the inclined planes, one at each end of the piece of ruby i.e. the lift is on the pallet. Note that the escape wheel teeth are cut on the skew to present a very narrow rubbing surface to the pallet. A platinum counterpoise is fitted at the other end of the pallet staff.

The pallet assembly gives the impression of being made for trial; being crudely made and poorly finished and built up out of a number of separate pieces, unlike that of cat. no. 129 which is made from the solid with what is obviously greater confidence.

Balance: Bimetallic two-armed balance with brass compensation weights secured by screws, and steel screws set in the rims at the ends of the arms. Diam. 24·2 mm, h. 2·1 mm.

Balance spring: Blued steel flat spiral spring of $8\frac{3}{4}$ open coils, pinned to an overhanging stud. A brass piece pinned to the last coil of spring acts as an amplitude limiting device with a steel piece on the balance cock. There is also a pin on one of the balance weights pointing upwards. The system appears to have undergone some adjustment and no longer works though it appears that it was intended to operate when the balance amplitude in one direction reached 230°. The blued steel index has a strong resemblance to that of cat. no. 129. It registers against a scale on the top plate marked 24, 18, 12 and 6 reading from left to right.

Going train:
Great wheel (fusee) 63 teeth
Centre pinion 16 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 60 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth each, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection – purchased by Ilbert from Wartski in 1930 (reg. no. CAI-1962).

Note
1. Britten 1982 quotes:

> Weston, William, 1790–1818; Smithfield, 23 Greenhills Rents 1790–1818; enameller; [& Willis] same pl. 1810 (Bri); 1806–16 (dir).

128 JOHN GRANT
c. 1800

WATCH MOVEMENT WITH DUPLEX ESCAPEMENT
Plates 91d–e, 92a–b

Signature: On the movement 'Grant, Fleet Street London No 2108'. On the dial 'GRANT Fleet Street LONDON 2108'.

Dial and hands: Flat enamel dial with intersecting offset minute and hour, and seconds circles, the dial secured by short feet and pins to the dial plate, of typical Arnold design.

Gold spade minute and hour hands, seconds hand missing.

Movement
Dial plate diam. 46·2 mm; front plate diam. 44·0 mm; back plate diam. 41·0 mm; frame h. 8·4 mm.

Frame: Full plate with four turned pillars, the back plate secured by pins.

Detachable barrel bridge. The dial plate, from which the hinge has been torn, attached to the front plate by four short feet and pins. The case catch and hinge mounted on the front plate under the dial. All the brass parts gilded.

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work on the front plate under the dial, the barrel arbor squared at that end only.

Jewelling: The pivots of the escape pinion arbor and balance staff in pierced jewels with endstones.

Escapement: Single wheel Duplex escapement, the brass escape wheel with integral resting teeth, impulse given by brass

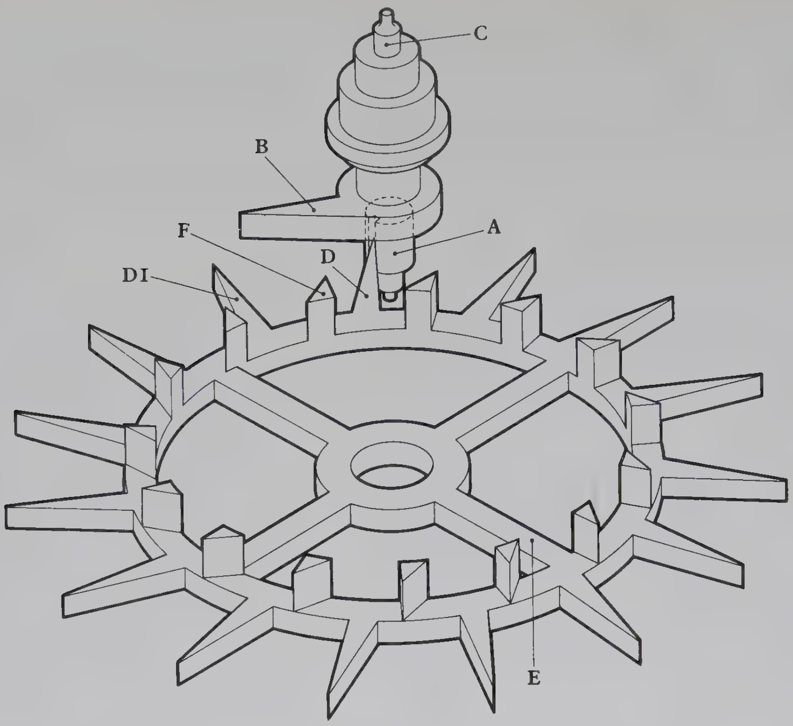


FIGURE 7
Duplex escapement

A	locking roller
B	impulse pallet
C	balance staff
D	locking tooth
E	escape wheel
F	impulse tooth

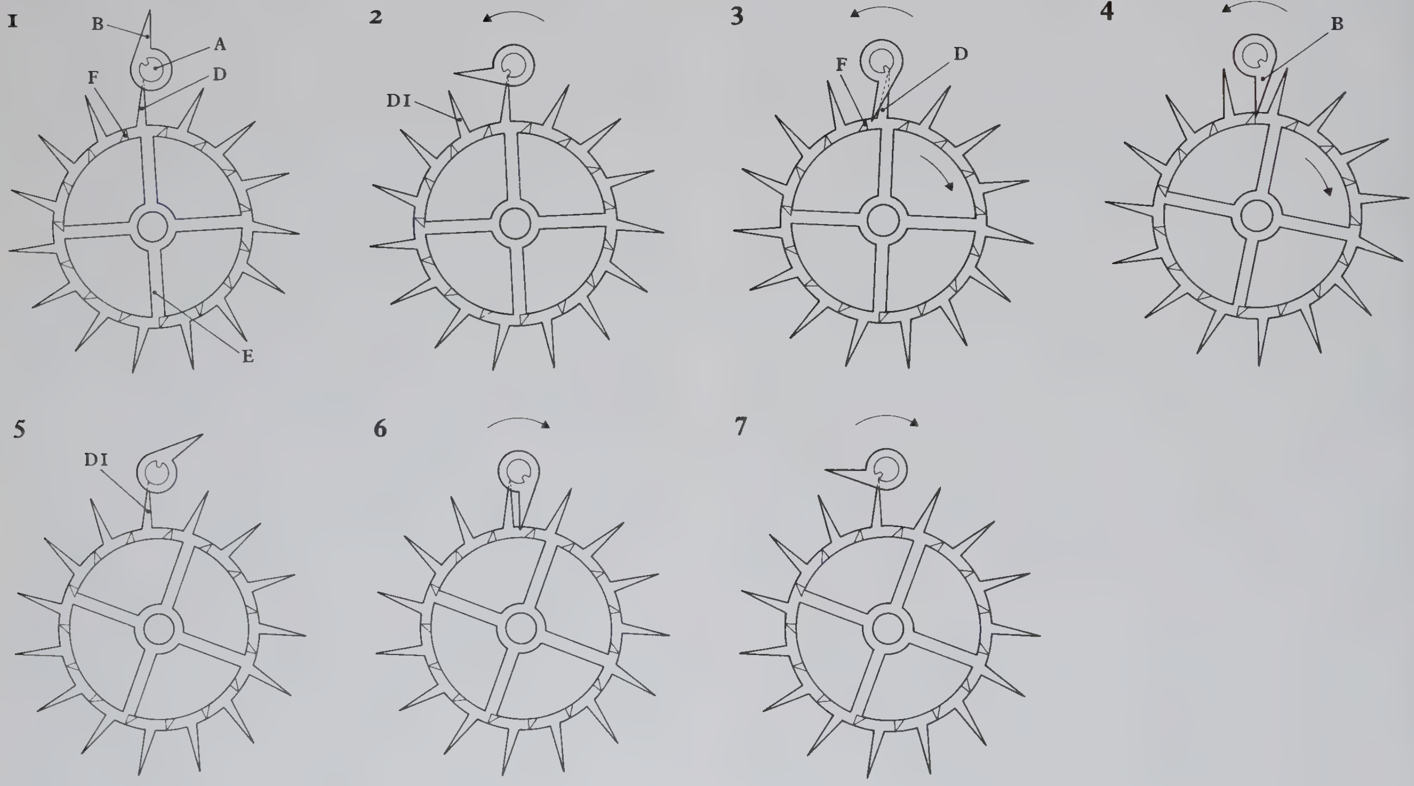


FIGURE 7A
Sequence of operations of Duplex escapement

1 Escape wheel E locked, locking tooth D resting on locking roller A. Balance rotating anticlockwise
2 Unlocking about to commence as locking tooth D enters notch on roller A
3 Locking tooth D about to leave notch, impulse tooth F about to hit impulse pallet B
4 Pallet B being pushed by impulse tooth F, thus impulsing balance
5 Locking tooth D resting on locking roller, escape wheel locked again
6 Balance returning, wheel still locked
7 Notch passes locking tooth as balance rotates clockwise, no action

pins set upright in the rim. The impulse pallet steel with ruby roller beneath (see figs 7 and 7a).

Balance: Bimetallic two armed balance with brass compensation weights secured by screws, and with steel screws set in the rims at the ends of the arms. Diam. 21·0 mm, h. 1·8 mm.

Balance spring: Blued steel flat spiral spring of 7¾ turns. The stud kept in place by a strong leaf spring of blued steel, not original. The stud as a result has limited movement.

Going-train counts:
Great wheel (fusee) 63 teeth
Centre pinion 14 leaves, wheel 75 teeth, no crossings
Third pinion 10 leaves, wheel 64 teeth, 6 arms
Fourth pinion 8 leaves, wheel 70 teeth, 6 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Provenance: Ilbert Collection; Ilbert purchased this watch in 1930 (reg. no. CAI-1347).

129 J. S. GARTLY[1]

1804

LEVER WATCH *Plates 92c–f, 93a–e, 94a*

Signature: On the barrel bridge 'John Gartly Aberdeen No. 445.'

Case: Silver consular case with the London hallmark for 1804 and the maker's mark R.G., with five-knuckle hinge, large stirrup pendant, and without case springs. Diam. 56·3 mm, th. over the glass 29.0 mm.

Dial and hands: Flat enamel dial with intersecting offset minute and hour, and seconds circles. The dial fixed to the dial plate by three feet and pins, and signed on the reverse 'Weslon' (see cat. no. 127).

Gold spade hands, seconds hand broken.

Movement

Dial plate diam. 47·6 mm; front plate diam. 45·6 mm; back plate diam. 44·3 mm; frame h. 9·1 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins and a screw, also retaining one end of the detachable barrel bridge. The dial plate carrying the movement hinge fixed to the dial plate by four short pillars and pins. The case catch and spring mounted on the front plate under the dial. A long bridge on the front plate with the lower bearings of the fusee, third and fourth wheel arbors. The front plate pierced to admit the lower pallet staff bearing screwed and steady pinned to an extension of the balance potance. The balance cock planted with its edge set in from the edge of the back plate. (compare with cat. no. 127).

Fusee: Keywind fusee with normal stop-work and maintaining power, the maintaining ratchet wheel brass, the detent return spring lodged under the great wheel and acting on a pin on the detent. The deeply flanged barrel with setting-up-work under the dial on the front plate, the arbor with an extended square on that end only.

Going train: The centre arbor offset, the fourth wheel a contrate. The escape pinion of only six leaves.

Jewelling: Only the pivots of the fourth and escapement arbors in jewelled holes, the lever and balance with endstones. The jewelling for each of the pivots of the escape arbor appears to consist of a pierced jewel and endstone set inside a short blind tube and cannot be dismantled.

Escapement: Two-plane lever escapement (see figs 8 and 8a). There is no draw, and the lift is on the pallets.

Balance: Plain gilded brass three-armed balance. Diam. 23·4 mm; h. 1·3 mm.

Balance spring: Blued steel spiral spring of 5½ opens turns, pinned to a brass collet and a gilded brass overhanging stud screwed to the back plate.

Thermal compensation: Sugar tongs device screwed to a brass block mounted on a blued steel index with a scale on the back plate.

Going-train counts:
Great wheel (fusee) 64 teeth
Centre pinion 16 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 60 teeth, 4 arms
Escape pinion 6 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1200).

Note

1. This watch was probably made by John Grant.

130 BREGUET ET FILS

1813

MARINE CHRONOMETER *Plates 94b–e, 95a–d*

Signature: At the bottom of the dial 'BREGUET'. On the back plate 'Breguet et fils No 2741'. On the inner back cover 'Premiere Piece ou la Comunication du Rouage au Régulateurs S'opère Sans Frotement. Executée en 1813 par Breguet No 2741 Pour Mr Belmas ami de l'auteur'. This can be translated as: 'The first piece where the transmission from the train to the regulator occurs without friction. Made in 1813 by Breguet for his friend, Mr Belmas'.

Box: The movement contained in an open-ended brass drum with two narrow rings standing proud on the inside. The front plate rests on one and the movement is held by three dog screws on the other. The dog screws are planted on the edge of the back

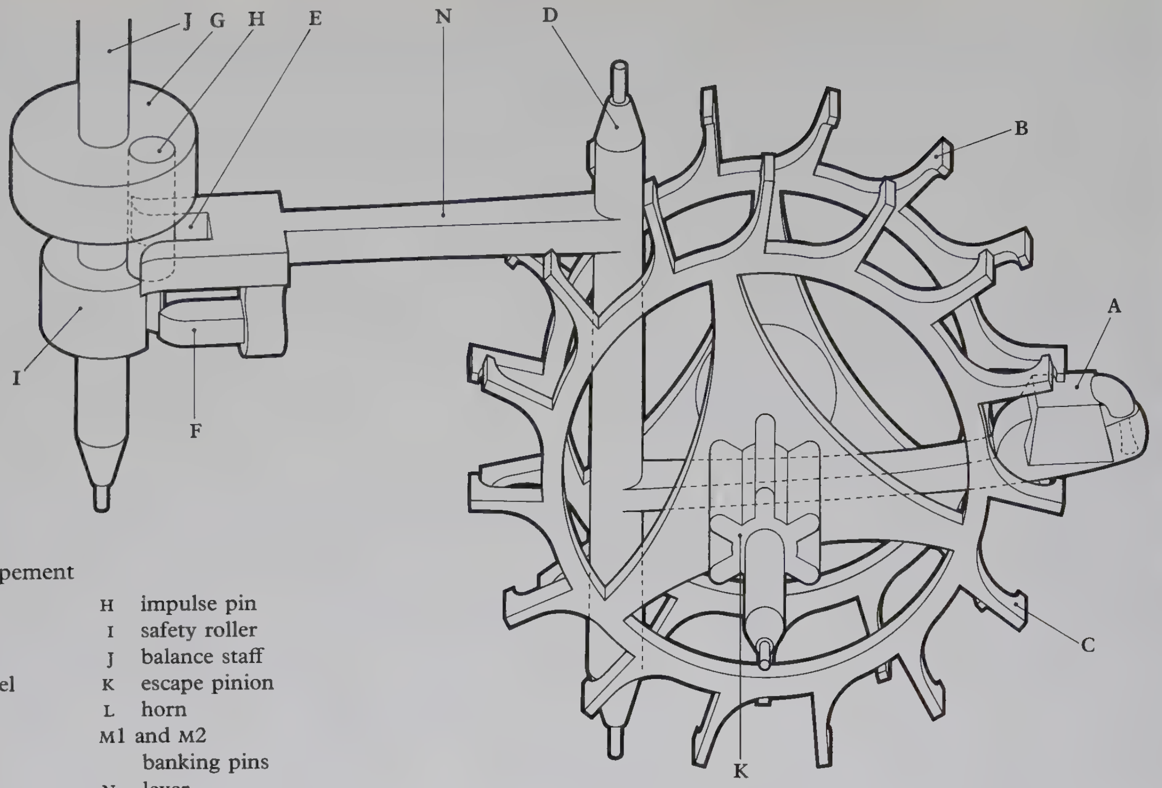


FIGURE 8
John Gartly's lever escapement

A	pallet stone
B	escape wheel
C	second escape wheel
D	pallet staff
E	notch
F	dart
G	impulse roller
H	impulse pin
I	safety roller
J	balance staff
K	escape pinion
L	horn
M1 and M2	banking pins
N	lever

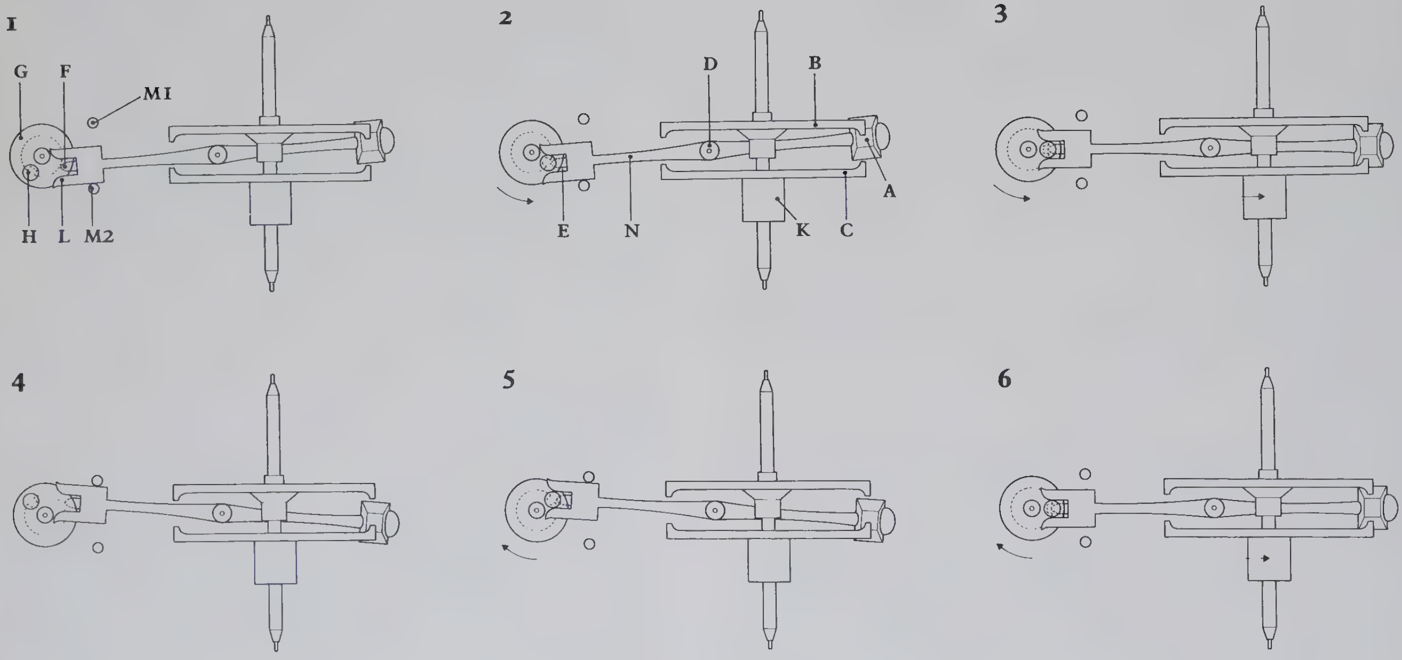


FIGURE 8A
Sequence of operations of John Gartly's lever escapement

1 Escape wheel B locked. Lever against banking pin M2
2 Impulse pin H entering lever notch E, unlocking about to start
3 Wheel unlocked and stone A giving impulse to lever N, this then impulsing balance
4 Impulse complete, escape wheel C locked on stone A
5 Unlocking about to occur on reverse swing of balance
6 Impulse being given by wheel C

plate. The inner back cover fits inside the back, it has two holes for a winder and a key, and two lugs fitting into slots in the drum, it is gilded on the outside. There is then a second cover fitting on the outside of the drum, again gilded on the outside. The dial is protected by a glazed cover fitting on the outside of the drum. The glass is flat, with a bevelled edge, and has a short blind hole over the cannon pinion. The cover is fixed in its correct relative position by a peg in the drum fitting into a notch in the cover, and two fixing screws going in from the side. The drum has a gilded band in the middle, on which are fixed a slide to operate the independent seconds train, and a squared arbor with female hole, held under a small plate for setting the minute hand of the independent seconds train. There are engraved instructions for these.

The drum containing the movement fits into a brass cradle heavily counterweighted with a hemispherical piece of brass, and lined with green silk. The cradle is gimballed in a well made and finely figured walnut box of the usual type. The gimbal assembly is locked by a threaded brass plug set in a brass plate in the centre of the bottom of the box. This can be screwed in and out from underneath by a male square on a key, and locks in a hole in the centre of the hemispherical counterweight. The box can be screwed to a wooden surface by two spring-loaded wood screws lodged in the side of the box. Each has a squared head, and when the key is applied they can be forced down and turned to screw them into the chart-room table, or a larger carrying box. They are normally held retracted by flat springs visible when the bottom of the box is removed. The box also has a lock with a shield-shaped escutcheon plate, and a sliding cover in the lid over a round aperture, but no carrying handles. The cover is centred with a diamond-shaped inset brass plate engraved 'No 2741 Breguet et Fils'. A large brass key is held under a brass clip inside the lid, it has a male square to operate the gimbal ring, and a female square to operate the spring-loaded fixing screws. A brass tipsy key fits in a brass ring in the side of the box, with a small male square for hand setting and a female square for winding the going train fusee. The latter is a steel shaft inside a thin-walled brass tube. Drum diam. 87·4 mm, overall h. 39·9 mm. Box base 174 mm square, overall h. 125·5 mm.

Dial and hands: Solid silver engine-turned dial, about 1·6 mm thick, held by a single screw at the centre in a recess in the drum containing the movement. The chapter rings for subsidiary seconds and independent recorded minutes are removable, being held by blued steel screws from the back. The central upper seconds dial and the left hand central and lower sector dials are for the going train and the reserve of going of the going mainspring respectively. The hands for these are of blued steel. The large right-hand central dial and smaller inset dial are for independent seconds and minutes, these have gold hands as does the reserve of going sector below for showing the state of wind of the mainspring driving the independent train. This train can be stopped and started at will, without affecting the going train, by a push-piece in the side of the drum.

Movement

The front plate, dial side, punched 2741.

Front plate diam. 83·1 mm; back plate diam. 80·2 mm; frame h. 18·5 mm.

Frame: Full plate construction with four turned pillars, the back plate retained by pins. The going and independent trains are all lodged in the frame, there are potances screwed to the back plate for the lower escapement bearings. There is also a potance on the inside of the front plate for the upper bearings of two of the independent train arbors. The brass parts are finished smooth with a mottle grain, the steel screws are grained.

Going-train fusee: Wound by a key from the back, and fitted with English-type stop-work and Harrison's maintaining power with a steel ratchet wheel. A dust-excluding collar is carried on the arbor square inside a tube held with its foot on the arbor bearing. The setting-up-work is mounted on the back plate, the barrel arbor is solid and unsnailed, the barrel flanged at the cover end. There is a bride for the last coil of the mainspring, the latter is hooked with an eye at both ends, and is clearly signed on the outside towards the outer end 'Vincent Juin 1813'.

Going train: Apart from the offset planting of the centre arbor, the train is of conventional construction and layout. The brass wheels are mottle grained, the steel pinions and arbors well finished and polished.

Jewelling: There is no jewelling in the front plate. The third and fourth rear pivots, and those of the escapement in pierced jewels, the latter with endstones set in straight-grained steel plates. The back plate bearing in a cock for the independent train fly pivot is a pierced jewel, otherwise this train has no jewels.

Escapement: In line club toothed lever escapement with divided lift. The gold escape wheel sunk out on both sides leaving only the ends of the teeth the full width. Every fifth tooth is drilled with a conical hole for oil, large at the back of the tooth and tapering to a small hole just below the locking corner. The exit pallet with jewelled concave impulse plane is integral with the fork in the usual way. The entry pallet also has a jewelled concave impulse plane. This is on a counterpoised arm pivoted on a centre line at about 45° to that of the rest of the escapement. A notch in the side of the pallet jewel engages with a gold pin on the main pallet frame where the entry pallet would normally be.

This system is to ensure that the impulse and locking friction are as near as possible equal on each pallet. There is no draw.

The fork and roller action is remarkable in that the normal impulse pin is replaced by a single long helix tooth formed on the edge of a gold roller. The fork is made conjugate to this, with short horns and a gold dart, with a small steel roller to ensure safety action. The helix is so well made that there is no sign of rubbing, the transmission of impulse being by perfect rolling contact, on the centre line. There is no sign even of a compression contact on the helix, a most remarkable achievement for 1813. The fork is, however, very heavy, and has a tail with a platinum counterpoise, the whole assembly having high inertia. Although the helical tooth on the impulse roller is wider at the tip than the root and curves around the roller, the fork notch is apparently straight but inclined to the axis of the balance staff at about 15°. In section it is of U-shape and polished along its length. Although the transmission of impulse occurs virtually without sliding friction in this arrangement, a component of the impulse is directed parallel to the balance axis instead of at right angles to it, and so is lost. The helix must also be made long to reduce its inclination, thus adding to the problems of inertia.

Balance: Bimetallic two-armed balance of aerodynamic design so that all the compensation, poising and quarter screws are faired inside the rim to present the minimum air resistance. The non-ferrous component of the rim is a whitish grey metal considerably tarnished. The break in each rim section occurs midway between the arms, the screws are of red gold. The steel part of the rim has been blued. Diam. of rim 28·35 mm, h. 2·78 mm.

Balance spring: Blued steel helical spring of just over 8 turns, with terminal curves at each end. The collet is brass with a slotted tail. The small steel stud is clamped by a plate with two screws on a steel platform with three levelling screws. The platform is held by a central screw on a brass cock overhanging the balance.

Independent seconds train: Driven by a small going barrel and consisting of four wheels and five pinions, planted on the edge of the frame partly between the plates and partly in a potance screwed to the front plate. The last pinion carries a steel two-armed flirt on the outside of the back plate. This can be held up by a pivoted arm with two-position jumper, operated by the slide on the edge of the movement drum. When freed it turns until it meets a brass slotted turret carried on the escape wheel arbor. This releases the flirt once per second, or at every fourth swing of the balance, and allows the independent train to advance. There is no means of returning the independent seconds hand to zero except by stopping it there, but the recorded minutes can be reset. A steel shaft carried on a bracket on the pillar carries a squared tube for the resetting male key. Motion is transmitted in a clockwise direction via a steel contrate wheel to a pinion on the end of an arbor passing through a hollow pinion. The latter pinion turns once in thirty minutes when the independent train is running, the recording hand being carried on the end of its central arbor. There is a tiny ratchet and click system on the resetting arbor, before the contrate wheel, so that resetting can occur only forwards. This is to prevent the flirt being turned backwards and possibly jamming in the turret if the friction in the hand setting mechanism should be greater than the driving torque. It also prevents the resetting arbor from rotating with the independent train while the latter is running.[1]

Independent going barrel, up-and-down and stop-work: The barrel is wound by a folding key on its squared arbor, it has a detachable cover on both ends, and two mainsprings separated by a central brass section in the middle of the barrel. Each spring is numbered and signed 'penpin mai 1812', and there are dots inside the barrel to indicate which side each spring should be fitted. Their dimensions are 3·65 mm × 0·12 mm and the barrel has a diam. of 13·3 mm. The barrel arbor is solid and unsnailed.

The end of the barrel arbor towards the front plate has an extended square, and then a pivot running in a cock on the front plate. A steel arbor fits on the square, threaded on its outside and with a steel nut running on the thread, edged with brass. A steel piece standing on the barrel cover fits in a slot in the steel nut. This arrangement operates as both up-and-down indicator and stop-work. When the arbor turns during winding the nut is carried towards the barrel until a projection on the threaded arbor encounters a projection on the underside of the steel nut. When the barrel turns during running the nut moves away from the barrel. A lever with an inclined plane in the path of the nut operates the indicator hand through another lever and pivoted arbor. The first lever is carried on an arbor pivoted in the frame with a brass piece squared to the end projecting through the back plate. This is moved into the path of the independent seconds flirt to hold up the train before the mainspring is completely run down.

Up-and-down indication for the going train: There is a reduced extension of the fusee arbor pivot in the front plate. This carries a two-armed steel piece held with a grub screw to index a brass sector carrying the indicating hand. The teeth of the sector are also acted on by a jumper spring.

Going-train counts:
Great wheel (fusee) 65 teeth, 8 turns of groove
Centre pinion 15 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 75 teeth, 4 arms
Escape pinion 10 leaves, wheel 16 teeth, 4 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Independent seconds train:
Barrel 72 teeth
First pinion 12 leaves, wheel 60 teeth
Second pinion 10 leaves, wheel 50 teeth
Third pinion 10 leaves, wheel 60 teeth
Fourth pinion 10 leaves, wheel 50 teeth
Fifth pinion 10 leaves, two-arm flirt engaging with a turret of 8 slots on the escape arbor

Provenance: Ilbert Collection; purchased by Ilbert from Contarde in 1934. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-2066).

Exhibited: 'Pendulum to Atom' under the auspices of The Worshipful Company of Clockmakers at Goldsmiths' Hall, London, October 1958.

Note

[1] The independent seconds mechanism invented by Moyse Pouzait in 1777.

Bibliography: Daniels 1975, pp. 85, 86; Bertele 1981, p. 202; E. Jacquet, *Le Musée D'Horlogerie de Genève*, Catalogue, Geneva, 1952, pp. 181, 182, fig. 104; L. J. Gay Lussac and Arago, *Chronomètres de Breguet*, 1819.

II.viii (cat. nos 131–146)

LATER PRECISION LEVER WATCHES

Once the correct proportions of the lever escapement had been established and draw introduced in about 1815 its popularity increased as the machinery required for its manufacture improved, because the escapement could not be made economically either by hand or with crude machinery.

Although it needed to be oiled, a major disdvantage when compared with the chronometer escapement, it is more robust, less liable to set and can be made smaller than the chronometer escapement. It is difficult to imagine a chronometer escapement in even a large wrist watch, for instance, and even if possible it would be a tour-de-force of craftsmanship.

All the watches in this section have draw in the escapement although admittedly there is very little in cat. no 131. Of the sixteen examples five have divided lift (cat. nos 135, 140, 142, 145 and 146) and the rest have lift on the pallets. Just over half of the examples have double rollers. The greatest variation is in the shape of the impulse pins which are D-shaped in cat. nos 131, 132, 133, 140, 141, 142, 143, 145 and 146, round in cat. nos 136 and 138; round with a small flat in cat. no. 144, rectangular in cat. no. 137 and triangular in cat. no. 139.

The shape of the impulse pin has an effect on the extra escaping angle over and above that required for impulse. This extra angle is required to ensure that it clears the edge of the notch. The best compromise is the D-shaped pin which is easy to make and fit, does not result in too much wear of the sides of the notch and requires the minimum of additional travel of the lever for the jewel to clear the notch. The triangular impulse pin was favoured on the Continent for high-class watches and possesses the same advantages as the D-shaped pin except that it is not so easy to make and fit and can lead to greater wear of the notch sides.

It will be noted that nearly half of the examples in this section have fusees (cat. nos 131, 132, 133, 136, 138, 141 and 144) with the rest having going barrels. Only one of the earlier examples with a going barrel is English and this is by the somewhat eccentric maker J. F. Cole. Other than this they are either in continental examples or later than 1880, the date when the going barrel was generally introduced into English work. However, from 1850 onwards Dents did produce high grade keyless wound and hand-set watches with going barrels.

131 JAMES FERGUSON COLE

c. 1820

LEVER WATCH MOVEMENT *Plates 95e–f, 96a–c*

Signature: On the back plate 'James Ferguson Cole No sk Inv^{t} et Fecit London'. Dial inscribed 'COLE LONDON'.

Dial and hands: Enamel dial, in the enamel on the back, 2.

Blued steel moon hands, the minute hand broken. Thin, finely tapered seconds hand with a long tail with pierced moon end, boss riveted but has screwdriver slot.

Movement

Dial plate diam. 52·7 mm; front plate diam. 50·6 mm; back plate diam. 48·6 mm; frame h. 7·6 mm; front plate th. 1·50 mm (reduced to 1·12 mm at the edge).

Frame: Similar to cat. no. 15.

Fusee: Similar to cat. no. 15 except for the stop-work piece and return spring made from a single piece of blued steel.

Going train: Similar to cat. no. 15.

Jewelling: Similar to cat. no. 15.

Escapement: There is evidence that the movement was originally intended to have a pivoted detent escapement similar to cat. no. 15. Holes were drilled in the back plate and then filled, with the exception of that for the detent banking screw. The watch is now fitted with a lever escapement.

The polished steel escape wheel has drilled and slotted teeth, for oil retention. One has broken as a result of the weakness of the tooth so produced. All the lift is on the escape wheel teeth, the drops are very heavy. The usual fork and roller action with a double roller, the fork tail banking against a pin. The heavy fork and pallet system is not poised and is positioned in such a way that it is virtually impossible to check the functioning of the escapement. There is draw in the escapement, although very little on the exit pallet.

Balance: Bimetallic balance with gold quarter and compensation screws. Diam. 22·8 mm, h. 1·6 mm.

Balance spring: Blued steel open coiled spiral spring with an overcoil pinned to a modified Breguet stud, brass collet. Index similar to cat. no. 15, again no shock protection for the upper pivot of the balance staff.

Going-train counts:
Great wheel (fusee) 60 teeth
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 16 leaves
Hour wheel 48 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1939 (reg. no. CAI-947).

132 ULRICH & CO.

1828–1832

LEVER WATCH MOVEMENT *Plates 96d–e, 97a–b*

Signature: On the back plate 'ULRICH & C^o^ Cornhill LONDON N^o^ 62'.

Case: Case missing, but was open face.

Dial and hands: Silver dial with engine-turned central decoration to the main dial and to the sunk subsidiary seconds dial, the numerals and divisions painted, the outer minute divisions almost erased. The dial retained in a recess in the front plate by a single blued steel screw below XII (see cat. no. 134 for a similar dial).

Blued steel hands, the minute hand not original.

Movement
Front plate diam. 52·4 mm; back plate diam. 48·1 mm; frame h. 8·4 mm.

Frame: Half plate construction with three turned pillars, with a separate cock for the pallets, the finely engraved back plate retained by sunk blued steel screws. A separate bridge on the dial side of the front plate, carrying the bearings of the third, fourth and escapement arbors. The movement was fixed in its case by a single peg and two small screws in the edge of the front plate. The minute wheel and pinion replanted to miss the dial retaining screw. All the brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work fitted in a shallow recess on the front plate under the dial. The barrel arbor with an extended square on that end only.

Going train: Well-made train with exceptionally high numbers of wheel teeth and pinion leaves. The steel pinion arbors and undercuts polished, the brass wheels gilded.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones. A diamond endstone set in a blued steel ring on the balance cock. The fusee, centre and third arbor upper pivots run in brass bushes held by screws in recessed holes in the back plate.

Escapement: Ratchet-tooth lever escapement with inset jewelled pallets and a fork with poising tail. A single roller on the balance staff, with a D-shaped impulse pin jewel. Banking for the fork provided by brass pins acting near the end of the fork. The pallet and fork assembly are not accurately poised in spite of a weight riveted to the underside of the fork tail and two pegs in drilled holes in the side of the pallet frame.

Balance: Bimetallic three-armed balance with three small brass poising screws set in the rim near the fixed ends, and three platinum compensation screws at each free end of rim. Diam. 21·4 mm, h. 2·1 mm.

Balance spring: Blued steel spiral spring of 9½ turns pinned to an elaborate polished steel stud on the balance cock and a round brass collet, without overcoil or terminal curve. An index snapping onto a boss on the underside of the balance cock concentric with the bearing has a long tail passing over an engraved scale on the back plate. In the middle of the scale the number 15 indicates fifteen small divisions on either side of centre.

Going-train counts:
Great wheel (fusee) 104 teeth
Centre pinion 14 leaves, wheel 112 teeth, 5 arms
Third pinion 14 leaves, wheel 105 teeth, 5 arms
Fourth pinion 14 leaves, wheel 96 teeth, 5 arms
Escape pinion 12 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1936 (reg. no. CAI-1167).

133 ARNOLD AND DENT

1833

MARINE CHRONOMETER *Plate 97c–f*

Signature: On the dial only 'Arnold and Dent, 84 Strand London No 823 WITH AIRY'S COMPENSATION'. The Admiralty arrow is engraved on the seconds dial and the back plate. No signature on the back plate.

Box: Similar to cat. no. 14, but still with its original top. Inside the lid an advertisement for E. Dent and Co., 61 Strand and 4 Royal Exchange London. The ivory disc set in the front of the top, engraved 'Arnold and Dent 823 two days' and the Admiralty arrow. The sides butted together at 45° and glued. The bottom still covered with old material with the addition of four later rubber feet.

The movement contained in a gimballed brass drum with threaded bezel and domed glass. A spring-loaded pivoted arm with lined cover protects the winding hole, there is a gimbal lock partly missing and a tipsy key numbered 843. Box 142 mm square, h. 145 mm excl. feet.

Dial and hands: Engraved, silvered brass dial, the engraving filled with black wax, attached to the front plate by three turned pillars and screws in the edge of the front plate. The pillars are turned with shoulders to leave a gap between the front plate and the underneath of the dial for the motion work.

Blued steel hands, bevelled on their upper surfaces.

Movement
Ebauche marks: Inside the front plate punched T.C.W. The main frame parts and underside of the dial numbered 823.

Dial diam. 87·9 mm; front plate diam. 58·2 mm; back plate diam. 57·1 mm; frame h. 15·5 mm.

Frame: Small two-day movement much smaller in diameter than the dial. Full plate construction with detachable barrel bridge and four turned pillars, the back plate retained by blued steel screws. The edge of the balance potance foot is radiused but not moulded. There are no visible signs that a detent escapement was ever fitted. A large late nineteenth-century dust-excluding sleeve is fitted over the winding square and secured by two screws onto the back plate.

Fusee: Fitted with Harrison's maintaining power and the usual stop-work with a brass maintaining ratchet wheel. Setting-up-work mounted on the detachable barrel bridge. The barrel arbor not snailed and made from the solid. No marks or signature on the inside of the fusee assembly. The mainspring, giving all appearances of being original especially the outer solid hooking, signed 'W. Smith Dec 7 1833'.

Going train: Well made and finished, the wheels riveted to their pinions.

Jewelling: The lower fourth arbor pivot in a pierced jewel, those of the escapement in pierced jewels with endstones. A diamond endstone set in a blued steel ring in the balance cock.

Escapement: Ratchet-toothed single roller English lever escapement giving every appearance of being original. There appear to be no filled holes in the plates, and the escape arbor is planted so far from the balance staff that a detent escapement could not have been fitted, for with normal proportions the escape wheel teeth would have intersected the fourth arbor.

The steel escape wheel, with the teeth slotted and polished and both faces also polished, is mounted on a brass collet on the escape pinion arbor planted between the plates. The steel pallet frame is jewelled and polished and mounted on an arbor planted between a potance under the back plate and the back plate itself. The gold lever is pinned to the top of the pallet frame and carries a brass guard pin to provide safety action against the polished edge of the steel roller. The ruby impulse pin is of D-shaped section. The fork and roller centre line is at right angles to the wheel and pallet centre line.

Balance: Later bimetallic two-armed balance secured by two screws to a brass collet in the balance staff. Two other screw holes in this collet at a different radius from the others are used for two more screws securing the Airy's bar under a brass disc. The bimetallic rim sections are each drilled and tapped for a number of screws towards their free ends. However brass weights are fitted instead of screws as screws are not suitable in conjunction with the Airy's bar. Diam. of rim 23·8 mm, h. 3·5 mm. This device was invented by Sir George Airy in 1871 to facilitate fine adjustment of the compensation (see Appendix). It consists of a steel crossbar shorter than and mounted above the main crossbar of the balance, carrying two small brass weights on thin springy arms, so that they are held in contact with the main rims. To make an adjustment to the compensation the small crossbar is rotated relative to the main one, and the small weights carried towards or away from the main weights (see also Gould 1923, pp. 203, 204). Two timing screws for mean time adjustment are set in the rim at the ends of the arms.

Balance spring: Steel helical spring, not blued, of just under 10 turns, with terminal curves. The split brass collet and brass stud are provided with round holes and D-shaped brass pins to clamp the ends of the spring. The diamond-shaped stud, fitted on the balance cock, has a screw for lateral adjustment.

Going-train counts:
Great wheel (fusee) 84 teeth, 8 turns of groove
Centre pinion 12 leaves, wheel 80 teeth, no crossings
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,000

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

Up-and-down indicator:
Pinion on the fusee arbor, 10 leaves, driving a wheel of 90 teeth.

Provenance: Admiralty service: According to the Chronometer Ledgers preserved at National Maritime Museum, Greenwich, No. 823's service with the Navy was as follows:

1 April 1835 Greenwich
2 August 1854 *Jackall*
17 February 1874 H.M.S. *Magpie*
28 May 1888 H.M.S. *Buzzard*
4 July 1892 H.M.S. *Anson*
3 March 1902 *Johannsen*
28 December 1913 *Bombay*
5 October 1917 H.M.S. *Repulse*
22 November 1930 Sold to C. A. Ilbert Esq.

Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1929).

134 JAMES FERGUSON COLE
c. 1840

LEVER WATCH MOVEMENT *Plate 98a–d*

Signature: 'James F. Cole London No q s'.

Dial and hands: Compare with Ulrich and Co., cat. no. 132. Engine-turned silver dial attached directly to the front plate by two short feet and pins. Back of dial scratched 'J. F. Cole 1/2' to mark the position of 12 o'clock and '8/99' and '7/1900' and 'Grohe no 112 2/56'. Another signature is unreadable.

Blued steel moon hands. Blued steel seconds hand and pipe integral and of unusual construction. Hands key set.

Movement

Front plate diam. 50·6 mm; front plate th. 3·25 mm; overall frame h. 7·1 mm.

Frame: Lepine construction built up on the massive front plate. The cocks finely engraved with acanthus leaf decoration. The movement was originally held in its case by two dog screws and two positioning pegs. The brass parts gilded, screws blued.

Going barrel: Keywound, the original stop-work removed, the ratchet wheel and combined blued steel click and spring of Breguet style. The arbor pivoted between the frame and the cock.

Going train: The fourth wheel has the unusual number of 75 teeth meshing with the escape pinion of 8 leaves. This allows an 18,000 train with the escape wheel of 16 teeth. The brass wheels gilded.

Jewelling: The centre arbor upper pivot and those of the third and fourth arbors run in pierced jewels. The conical pivots of the escape, pallet and balance arbors in blind cone-shaped holes in round jewels. The balance upper bearing a pierced jewel and diamond endstone.

Escapement: In line ratchet tooth lever escapement, the heavy pallet frame with inset jewels. The pallet arbor outside the balance. Very wide jewel impulse pin on the table roller. This may resemble the roller jewels in later Savage escapements but impulse is not given through the engagement of a notch in the roller and a pin on the lever. It is in fact not good practice to have such a wide impulse pin if it is receiving the impulse, which will then be delivered far from the centre line. The heavy fork with long tail pinned to the lever frame, the assembly not poised. The banking pins on a detachable brass plate.

Balance cock: With a divided scale and S.F. (for 'Slow' and 'Fast').

Balance: Bimetallic two-armed balance with gold quarter and compensation screws. Diam. 18·0 mm, h. 1·4 mm.

Balance spring: Spiral steel spring of 15 turns without overcoil brass collet. Breguet-type stud under a steel plate on the balance cock. Polished steel index.

Going-train counts:
Great wheel (going barrel) 90 teeth
Centre pinion 10 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 75 teeth, 6 arms
Escape pinion 8 leaves, wheel 16 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 12 leaves
Hour wheel 36 teeth, minute wheel 40 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1941 (reg. no. CAI-946).

135 E. J. DENT
c. 1846

SPLIT SECONDS LEVER WATCH MOVEMENT
Plates 98e–f, 99a

Signature: On the barrel cock 'E. J. Dent Compound Movement'.

Dial and hands: Engraved silvered brass dial retained by a single screw in the upper half, the subsidiary time of day dial recessed in a hole in the main dial and held by two screws from behind. The dial signed in the upper half; 'E. J. DENT Chronometer Maker to the Queen No 10951', also scratched on the back 10951.[1]

Blued steel hands. Two centre seconds hands, the tip broken off one of them.

Movement

Front plate diam. 47·3 mm; front plate th. 3·0 mm (sunk out); frame h. 6·0 mm.

Frame: Open Lepine construction built up on either side of the recessed front plate, the brass parts gilded. The movement was retained in its case by two positioning pegs and two dog screws. No dial plate or dust cover. The balance cock engraved with scrolling foliage and with F.S. and a scale for the index.

Going barrel: Hanging barrel supported by a cock, the barrel ratchet mounted on the side of the cock in typical Swiss manner. A steel barrel bridge beneath the dial finished with a brass bush for supporting the lower barrel pivot.

Going train: The brass wheels polished flat and not gilded. The hollow centre arbor offset and driving the motion work, also offset, directly. The fourth arbor planted at the centre and carrying the lower sweep centre seconds hand.

Jewelling: The pivots of the third, fourth and escapement arbors run in fine pierced jewels. The balance staff pivots in pierced jewels with endstones.

Escapement: Right-angled club-toothed lever escapement with polished steel escape wheel, one piece pallet frame and fork, and table roller on the balance staff. Jewelled pallets and oval-shaped impulse pin, divided lift. No banking pins, banking on the sides of the plate recess, a continental feature.

Balance: Bimetallic two-armed balance with gold timing and compensation screws, a steel screw in the rim at the ends of the bar and two small brass screws. Unusually large gaps in the bimetallic rims. Diam. 17·6 mm, h. 1·2 mm.

Balance spring: Blued steel open coiled spiral spring pinned to a round collet on the balance staff, and with an overcoil and terminal curve pinned to a Breguet stud clamped under a steel plate on the balance cock, probably not original. A polished steel index held by the upper steel endstone plate on the balance cock.

Stop/catch-up mechanism for the upper sweep centre seconds hand. A push-piece in the pendant is made to advance a star wheel with jumper by one tooth space at a time. On the underside of the star wheel is a series of indentations corresponding with every alternate tooth space. A steel rod passing through a hole in the front plate is caused to move up and down as the star wheel rotates. This rocks a spring-loaded steel system pivoted like a see-saw about a shoulder screw on a block on the back of the front plate. The hollow fourth arbor has an extended pivot at both ends, on the front to carry the lower sweep centre seconds hand, and on the back sliced off at 45° to the axis. Down the hollow arbor passes a steel rod with the other seconds hand on the front end and a mushroom-shaped piece on the end of a short tube also sliced at 45° on the other end. In one position of the star wheel the mushroom-shaped end is held down with the two 45° faces in contact, thus the arbor and rod are held relative to each other and the two seconds hands coincide one above the other and move round together. In the other position of the star wheel, the mushroom-shaped piece is withdrawn, whereupon the upper seconds hand stops. A further advance of the star wheel causes the upper seconds hand to catch up the lower and move round with it again.

The mechanism is an early example of split-seconds work for timing short intervals.

Going-train counts:
Great wheel (going barrel) 96 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 10 leaves, minute pinion 8 leaves
Hour wheel 32 teeth, minute wheel 30 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Desoutter in 1935 (reg. no. CAI-981).

Note

1. Nos 10950 and 10952 were recorded in Dent's books as manufactured by Gibbons and appear in 1846. No. 10951 is not mentioned and so was probably bought in as a complete watch from Switzerland and sold by the firm.

136 VICTOR KULLBERG

c. 1880

LEVER WATCH MOVEMENT *Plate 99b–e*

Signature: On the back plate 'Victor Kullberg London'. On the front plate numbered under the dial '3067'.

Case: No case, but was open face.

Dial and hands: Flat enamel dial with sunk subsidiary seconds dial, not signed. On the back signed 'Willis'. Three feet and pins to retain the dial to the front plate.

Blued steel spade hands.

Movement

Ebauche marks 16 J.P i (Joseph Preston of Prescot); also the number 3067.

Front plate diam. 44·2 mm; back plate diam. 42·3 mm; frame h. 7·0 mm.

Frame: Typical half plate construction for an open face calibre without a separate bridge on the dial side of the front plate for the train and escapement arbor bearings.

Fusee: Reversed fusee with the usual one-piece stop-piece and spring for the stop-work but these are missing, and with a steel maintaining ratchet wheel. The setting-up-work under the dial on the front plate in a recess. The fusee arbor squared at the back even though keyless work is fitted.

Going train: Typical layout and construction with a reversed fusee, the fourth wheel above the third, the centre arbor hollow for the hand-set arbor carrying the cannon pinion.

Jewelling: The third and fourth going train bearings jewelled, also the escapement with endstones. A diamond endstone in the balance cock. The going train jewels *bombé*.

Escapement: Right-angled ratchet-tooth lever escapement. The brass escape wheel and polished steel pallet frame with inserted jewels of typical construction. The polished steel fork pinned to the pallet frame of standard design and fitted with a brass dart pinned to the underside of the fork behind the notch. Black polished steel double roller with a round ruby impulse pin. The escape and pallet upper bearings in a bridge. The banking pins acting on the fork tail.

Balance: Bimetallic two-armed compensation balance with gold screws and quarter screws. Diam. 17·8 mm, h. 1·6 mm.

Balance spring: Blued steel spiral spring with overcoil and terminal curve, free sprung to a diamond-shaped stud on the balance cock. The collet of polished steel with two flats.

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 16 leaves, minute pinion 8 leaves
Hour wheel 48 teeth, minute wheel 32 teeth

Keyless work:
First rocking bar wheel bevelled teeth 30
First rocking bar spur teeth 48
Pinion on the end of the pendant winding arbor 12 leaves (the winding arbor still with the watch)
Second rocking bar wheel 48 teeth
Wheel threaded on the fusee arbor 56 teeth
Intermediate hand-set wheel 14 teeth

Kullberg fusee keyless work: As described in *HJ*, April 1869, and by D. Glasgow in *Watch and Clock Making*, 1885 edition, pp. 270–72, though cat. no. 136 differs slightly in detail from the description in *HJ*.

The winding button turns a shaft in the pendant ending in a spur-toothed pinion. This pinion is in permanent mesh with the bevel teeth of a steel wheel on a rocking bar. The spur teeth on the edge of this wheel are in permanent mesh with those of another steel wheel also pivoted on the rocking bar by a shoulder screw. The rocking bar itself is acted on by a strong spring so that the first wheel is held out of mesh with a steel wheel threaded onto the fusee arbor. On turning the winding button to wind, the first steel wheel moves across with the rocking bar, meshes with that on the fusee arbor and the fusee is turned to wind the mainspring. On releasing the winding button the spring acting on the rocking bar returns, and thus the wheels move out of mesh.

To set the hands: A push-piece in the case middle communicates with another in contact with the rocking bar. On applying pressure to the push-pieces the rocking bar moves until the second rocking bar wheel meshes with the intermediate hand-set wheel. On turning the winding button the hands can be set to time.

The first rocking bar wheel turns on a shoulder on the rocking bar itself. The wheel is recessed on its upper surface for a grained steel washer, having a screw at its centre passing through both the washer and the rocking bar and into the front plate. This screw is prevented from turning by a steel pin passing through its edge, the washer beneath, and into the front plate. This arrangement allows the wheel to turn freely and the rocking bar has freedom to move sideways carrying the wheel. This latter freedom is limited by a short stud in the front plate passing into a rectangular hole in the rocking bar. The rocking bar also has a short tail on the end remote from the first steel wheel, held in contact with a brass peg in the front plate by the strong spring acting on the rocking bar so that the second rocking bar wheel touches a combined click and spring. This arrangement produces enough friction to throw the first steel wheel on the rocking bar across and into mesh with the wheel on the fusee arbor when the winding button is turned the other way, to wind. When it is turned the first wheel returns and the teeth of the second wheel pass over the click.

Provenance: Ilbert Collection, purchased by Ilbert from Cox of Clerkenwell in 1932 (reg. no. CAI-1031).

Bibliography: For details of Kullberg's life and work see his obituary, *HJ*, August 1980, pp. 185–7; 'Our Portrait Gallery', *Invention and Inventors' Mart*, 17 October 1885, pp. 1083, 1084; Otto Habinger, 'Victor Kullberg ein schweidischer Chronometermacher: *Alte Uhren*, October 1984, pp. 21–28.

137 VICTOR KULLBERG

c. 1880

LEVER WATCH MOVEMENT *Plate 100a–d*

Signature: On the back plate 'Victor Kullberg 105, Liverpool Road, London, No 4174', and a number of awards. On the dial below XII 'Victor Kullberg London 4174'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, retained by two feet and pins, and signed at the back faintly in red 'Kullberg 4174', the number partly removed when the seconds dial was inserted.

Blued steel hands of elegant shape and proportions.

Movement
Ebauche marks: 18 J.P 2 (Joseph Preston of Prescot).

Front plate diam. 46·2 mm; back plate diam. 43·5 mm; frame h. 7·9 mm.

Frame: Typical half plate construction for a hunter calibre.

Going barrel: Typical construction with four-turn Geneva stop-work fitted on the end of the barrel. The stop-work finger piece squared to the barrel arbor and having an extended cannon pivoting in the front plate.

Keyless work: Typical English rocking bar keyless work. The ratchet wheel retained on the squared barrel arbor by a steel plate and screw in a recess in the ratchet wheel.

Going train: Typical layout and construction, the fourth wheel below the third, the centre arbor hollow for the squared hand-set arbor carrying the cannon pinion.

Jewelling: All the going train bearings jewelled as far as and including the centre arbor. The escapement bearings jewelled and with endstones, a diamond endstone in the balance cock. The train jewels *bombé*.

Escapement: Victor Kullberg in line ratchet tooth lever escapement. The escape wheel brass, the polished steel pallet frame with inset jewels, pinned to the poised polished steel fork. The fork notch of dovetailed shape, the horns very short. The polished steel impulse roller consisting of a thick-walled cylinder with a single slot for both the projecting rectangular-shaped impulse jewel and also for the passing hollow, effectively a double roller. The slot slightly rounded where it functions as the passing hollow, in conjunction with a gold dart riveted to the underside of the fork.

Balance: Bimetallic two-armed compensation balance with gold screws and quarter screws, protected by two polished steel screws set in the front plate. Diam. 18·3 mm, h. 1·55 mm.

Balance spring: Blued steel spiral spring of 16¼ turns with an overcoil and terminal curve, free-sprung to a diamond-shaped stud on the balance cock. Polished steel collet with two flats.

Going-train counts:
Great wheel (going barrel) 90 teeth
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 14 leaves, minute pinion 8 leaves
Hour wheel 48 teeth, minute wheel 28 teeth

Keyless work:
Central rocking bar wheel 52 teeth
Intermediate winding wheel 36 teeth
Intermediate hand set wheel 24 teeth
Winding ratchet wheel 54 teeth
Hand set transmission wheel 18 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1935 (reg. no. CAI-1030).

Bibliography: See cat. no. 136 for details.

138 HUNT AND ROSKELL

1860–1910

KEYLESS GOING BARREL TIMEPIECE
Plates 100e–f, 101a

Signature: On the back plate 'Hunt and Roskell 156 New Bond Str^t London No 12923. Lever Escapement by V. Kullberg 1913'.

Case: No case, but was open face.

Dial and hands: Flat enamel dial with sunk subsidiary seconds and up-and-down dials.

Blued steel spade hands.

Movement
Ebauche marks: 16 J.P. 2 (Joseph Preston, Prescot) (see cat. no. 137).

Front plate diam. 44·4 mm; back plate diam. 42·4 mm; frame h. 7·6 mm.

Frame: Typical half plate construction for an open face calibre.

Fusee: The usual stop-work with integral stop-piece and spring, and maintaining power with steel ratchet wheel. Setting-up-work under the dial on the front plate in a recess. The fusee arbor squared at the back even though keyless work is fitted. Two pegs and a dog screw for securing the movement in the case.

Going train: Typical layout and construction.

Jewelling: All the going train bearings jewelled as far as and including the centre arbor. The fourth jewel in the cock not in a setting. The escapement bearings jewelled and with endstones. Diamond endstone in the balance cock in a blued steel ring.

Escapement: Typical English ratchet-toothed lever with table roller. The escape wheel brass, the pallet frame and fork polished steel, the banking pins working on the fork tail, round jewel impulse pin.[1]

Balance: Bimetallic two-armed compensation balance with gold screws and quarter screws. Diam. 18·1 mm, h. 1·8 mm.

Balance spring: Blued steel spiral spring with overcoil and terminal curve, free sprung to a diamond-shaped stud on the balance cock. The collet of polished steel with two flats.

Provenance: Ilbert Collection (reg. no. CAI-1150).

Note

1. Holes are provided in the front plate for a spring detent, and the type of banking piece fitted concentric with the balance axis. The excape wheel and pallet cock has one steady pin cut off and another fitted in a new position, and a steady pin hole has been filled in the front plate.

There seems little doubt that a detent escapement was originally fitted, and later removed by Victor Kullberg who substituted a standard lever escapement that would fit in the space available. The engraved inscription could then have been added to the back plate and the frame regilded. This would also account for the shallowness of the engraving of the original inscription. The gilding on the balance cock and fourth cock a different colour to the rest.

139 NICOLE, NIELSEN & CO.

Late 19th century

DOUBLE-DIALLED SPLIT-SECONDS CRONOGRAPH

Plates 101b–f, 102a

Signature: In the upper half of the time of day dial 'NICOLE NIELSEN & CO. 14 SOHO SQ. London'; repeated on a sunk disc opposite the subsidiary seconds dial at the back of the watch.[1]

Case: Later aluminium case with glazed front and back. The pendant with a silver bow, and a button held by a screw on the pendant arbor.

Diam. 53·8 mm, overall h. 21·3 mm.

Dial and hands: Flat enamel time of day dial snapped into a bezel and signed on the back in red 'Nicole Nielsen' and some other letters almost erased.

Another flat enamel dial on the back of the watch also held snapped into a narrow bezel, with sunk subsidiary seconds dial. The outside of the dial divided in fifths of seconds and seconds, with arabic markings for each five-seconds interval up to sixty, and traversed by split-seconds recording hands. At the thirty-seconds division is a small sector for a regulator hand which is mounted on an arbor carrying a cam on which an extension to the index tail rests. 'Nicole Nielsen' also discernible in the enamel on the back of this dial.

All the hands of blued steel.

Movement

Ebauche marks 8651 and 8519 on the plate under the rear dial.

Front plate diam. 45·3 mm; back plate diam. 43·7 mm; frame h. 6·3 mm.

Frame: Unusual three-quarter plate construction with the rear dial on the outside of the massive main plate. This plate recessed out for the going train, and with a circular sub plate carrying the escapement bearings. The back plate, under the time of day dial, also recessed for the going train and screwed and steady pinned to the main plate. No evidence of how the movement was originally held in its case, except a short, stout peg set in the edge of the main plate, and the steel bridge carrying the inclined transmission winding wheel.

Going barrel and keyless work: Normal going barrel fitted with a four-turn Geneva stop-work on the cover end, and the arbor pivoted in the main plate. The great wheel teeth cut on the other end of the barrel, the arbor on this end passing through the back plate in which it pivots, and with an extended square carrying a ratchet wheel on the outside of the plate. A click and spring provided in a recess beside the ratchet wheel. Another steel wheel having spur teeth pivoted on top of the ratchet wheel on a steel plate held by two screws passing into the ratchet wheel. On the underside of the steel wheel a ratchet and click are fitted, the ratchet meshing with the teeth of the lower ratchet wheel. The spur wheel is in mesh with a bevel wheel mounted on a plate at the pendant and inclined at an angle so that its teeth can also mesh with another bevel wheel on the end of the winding arbor. On turning the winding arbor to wind, all four wheels turn and the spring is wound. On reversing the direction of wind the winding ratchet wheel does not turn, but the other three wheels do.[2]

Hand setting: Beside the spur wheel concentric with the winding ratchet wheel another smaller spur wheel is planted, in constant mesh with the former. The latter wheel is pivoted on a shoulder screw on a steel arm, itself pivoted and with a return spring on the underside of the back plate. A push-piece beside the pendant, in the band of the case, connects with the steel arm. If pressure is applied to the push-piece the steel arm pivots until it reaches a stop, the steel wheel carried on it is then in mesh with another similar wheel under the minute wheel. On turning the winding button the hands can be set. Since all the winding work turns at the same time, the hands must be set before the mainspring is fully wound, or they can only be set one way.

Going train: The centre wheel offset, its arbor hollow and carrying the minute wheel and pinion on an arbor held friction tight. The minute wheel driving the loose cannon pinion with a 1:1 gear ratio and so being required to turn once per hour. The remainder of the train is as usual. The brass wheels gilded, the pinions well finished and polished.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escapement with endstones. The central chronograph arbor pivots also carried in pierced jewels. The pierced jewels *bombé*.

Escapement: English ratchet-toothed right-angle escapement. The pallet frame slotted and jewelled, the steel two-piece double roller with a triangular impulse pin. All the steel parts of the pallet frame, fork, dart and rollers very highly polished. The pallet frame and fork secured and positioned by a single screw and the pallet arbor.

Balance: Bimetallic two-armed balance, the arms of sage-leaf pattern. Gold quarter and compensation screws. Diam. 20·3 mm, h. 0·85 mm.

Balance spring: Blued steel spiral spring of 18½ tight coils, with an overcoil and terminal curve. A polished steel stud held by a screw on the balance cock and a round brass collet.

Index and Regulator: A polished steel index free to move on a boss on the balance cock, with a double tail acted on by a light spring holding one of the tail ends against a heart-shaped cam. An arbor pivoted in the main plate carries the cam on one end and the stout indicator on the other for adjusting the rate.

Chronograph mechanism: One push-piece in the band of the case operates the start, stop and return to zero of the upper chronograph hand. The lower chronograph hand normally follows exactly beneath the upper unless the split seconds mechanism is in operation.

The chronograph mechanism is controlled by a star wheel and jumper, and a pillar wheel. Motion is transmitted to the central fine-tooth brass chronograph wheel by a pinion in the upper end of its arbor. This arbor is pivoted in the main plate, and in a steel arm so that it can rock and cause the steel wheel to move in and out of mesh with the brass wheel. There is a brake lever, and a return to zero lever working with a heart-shaped cam on the chronograph wheel arbor, as in a modern chronograph mechanism of this type. The sequence of operations can be summarised as in the table, starting with the chronograph hand at zero.

	First Pressure	*Second Pressure*	*Third Pressure*
	on the push-piece in the band of the case		
Rocking pinion mechanism	engaged	disengaged	disengaged
Brake arm	withdrawn	applied	withdrawn
Return to zero arm	withdrawn	withdrawn	applied

There is no means of recording intervals of time of more than one minute's duration.

Split-seconds mechanism: Closely resembling a modern mechanism of this type. Another star wheel controlled by a jumper is operated by another push-piece in the band of the case near that for the chronograph. It causes two arms to hold or release a light steel wheel pivoting on the chronograph hand arbor and with a short cannon for the split-seconds hand. On the underside of this wheel is a lever and light spring operating on a heart-shaped cam fixed to the chronograph hand arbor. When the wheel is free, with the chronograph mechanism running, the two hands move together. If the split-seconds push-piece is operated, the wheel is held up and the split-seconds hand stops. A second pressure on the same push-piece causes the hand to catch up, because the lever on the underside of the wheel moves to the smallest radius on the heart-shaped cam, under the influence of its spring. This causes the wheel and hand to turn, until the hand catches up and coincides with the chronograph hand.

Going-train counts:
Great wheel (going barrel) 76 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Chronograph rocking pinion 12 leaves, carrying a fine-toothed steel wheel of 1·08 mm diam., driving a fine-toothed brass chronograph wheel of 6·86 mm diam.

Motion work:
Cannon wheel 70 teeth, minute pinion 7 leaves
Hour wheel 84 teeth, minute wheel 70 teeth

Winding wheels:
Pendant bevel wheel 11 teeth driving
an offset bevel wheel 19 teeth driving
The large wheel concentric with the barrel ratchet, of 52 teeth in mesh with
a steel hand-set wheel of 23 teeth.
The steel wheel concentric with the minute wheel and pinion has 17 teeth.
The winding ratchet wheel has 50 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1938 (reg. no. CAI-1122).

Notes

1. Emile Nielsen of Soho Square died in 1899.
2. In 1844 Adolphe Nicole patented a type of fusee keyless work (No. 10,348). The patent included a chronograph with heart-shaped cam. In 1862 he patented an improved chronograph with a pillar wheel control (No. 1,461). This watch follows Swiss practice in many respects.

140 A. LANGE & SÖHNE
c. 1881/2

LEVER WATCH MOVEMENT *Plate 102b–f*

Signature: On the back plate 'A Lange & Sóhne Glashútte b Dresden 16039'. On the enamel dial 'A LANGE & SÖHNE, GLASHÜTTE H/DRESDEN'.

Case: Silver case, the glazed front and back bezels snapping onto the middle. The winding button and hand-set push-piece (now missing) protected by threaded caps. The bow on a swivelling ring. Both glasses flat with bevelled edges.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, retained by two feet and screws set in the edge of the front plate.

Blued steel spade hands.

Movement

Ebauche marks 16039 on the front plate under the dial.

Front plate diam. 46·1 mm; back plate diam. 43·7 mm; frame h. 7·4 mm.

Frame: Three-quarter plate construction, with four turned pillars, the back plate retained by recessed blued steel screws. Separate bridges on the front plate under the dial for the barrel bearing, and for the train and escapement bearings except the centre arbor. The movement retained in its case by two polished steel dog screws on the edge of the front plate and a steel peg later filed flush with the edge of the plate. All the brass parts nicely electro-gilded.

Going barrel: Fitted with four-turn Geneva stop-work on the cover end. The arbor pivot in the back plate carried in a separate bush held in place by two polished steel screws. The outer end of the mainspring hooked with an eye to the barrel wall, and with a bride a quarter turn away from the hooking passing into slots in the cover and bottom.

Keyless work: The winding stem in two pieces, the button attached to a short arbor with a female square on the other end. The other part of the arbor with a male square, pivoted in the frame and carrying the crown and castle wheels. These two wheels provided with return springs under the dial, and an operating lever and spring combined on the inside of the front plate. The intermediate winding wheel divided in two with a bevel wheel on the inside of the front plate and a wheel meshing with the barrel ratchet wheel on the outside of the front plate. These two wheels screwed together and with an offset pin to prevent them turning. The barrel ratchet wheel held on a square on the barrel arbor by a single dog screw, a feature of watches by Lange.

Going train: Of adequate but not exceptional quality, the undercuts on the pinions nicely turned, the wheels electro-gilded. A small hole of crescent shape pierced by the third upper bearing to view the centre wheel, third pinion gearing. Another similar hole by the fourth lower bearing to give a view of the third wheel, fourth pinion gearing. The centre arbor hollow for an arbor carrying the cannon pinion. The great wheel and centre pinion of round-bottomed form, the rest of the going train square-bottomed tooth form.

Jewelling: The centre arbor rear pivot, and all those of the other going train wheels in pierced jewels, their surfaces flat against the pivot shoulders. The escapement arbor pivots in pierced jewels with endstones, a diamond endstone in a polished steel setting in the balance cock. All the jewels on the back in screwed gold settings, those in the dial plate rubbed in. Two polished steel endpieces on the front plate, one with the balance endstone, the other with both the pallet and escape wheel endstones. These two endplates retained by screws from inside the plate.

Escapement: In line club-toothed lever escapement with divided lift. Both the escape wheel and pallet frame gold. The escape wheel of especially high quality. The ruby impulse pin set in a boss integral with the bottom of the balance, the polished steel small roller fitted on the balance staff. The enclosed pallets jewelled, the entry impulse face concave, the exit convex. Banking provided by a pin on the underside of the pallet frame near the entry pallet, working in a hole in the front plate.

Balance: Bimetallic two-armed balance, cut like a Guillaume balance, but blued, so the ordinary type. Gold quarter screws, the rim slit to give a friction fit to the screws. Balances for Lange watches were made by Griesbach in Glashütte. Diam. 17·3 mm, h. 1·2 mm.

Balance spring: Blued steel spiral spring of 12¾ turns with an overcoil and outer terminal curve, the point of attachment of the spring to the collet in an unfavourable position. A brass collet on the balance staff, and a brass stud held on the balance cock with a steel screw in a shaped and countersunk slot.

Balance cock: With an acanthus leaf motif engraved decoration. The index provided with a rack and pinion fine adjustment.

Going-train counts:
Great wheel (going barrel) 90 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth
Pinions square-bottomed, wheels round-bottomed tooth form

Keyless work:
Crown wheel 14 bevel and ratchet-shaped teeth
Castle wheel 14 ratchet and 18 bevel-shaped teeth
Intermediate hand-set wheel 30 teeth
Intermediate winding bevel wheel 30 teeth, spur wheel 49 teeth
Barrel ratchet wheel 68 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1135).

Bibliography: For further biographical details about the firm of A. Lange and Söhne and the founder, Adolphe Lange, see Chamberlain 1941, pp. 425–7 and 440–9. See also Gerrit A. Nijssen, 'Glashütte and its Watch Industry', *Bulletin of the National Association of Watch and Clock Collectors*, August 1976, vol. 18, no. 4, pp. 284–301.

141 W. G. SCHOOF (1830–1901)

c. 1888

MARINE CHRONOMETER *Plate 103a–d*

Signature: On the dial only 'W. G. SCHOOF 99, St John Street Road Clerkenwell LONDON Nº 6059'. 'Schoof's Resilient Escapement', this last in red, and the Admiralty arrow; the arrow also appears on the back plate.

Box: The movement contained in a brass bowl, gimballed in a brass-bound mahogany box. The bowl has a flat glazed threaded bezel and the gimbal ring is fitted with a lock. A tipsy key fits in a hole in a corner plate. There is a glazed panel in the top of the box under a hinged lid with fitted catch. The box has flush fitting handles, a lock, and a rectangular ivory plate in the front of the top, engraved 'W. G. SCHOOF 6059' and the Admiralty arrow. Box 182 mm square, h. 190 mm.

Dial and hands: Engraved, silvered, flat brass dial held by three screws and a positioning peg in a recess in the dial plate. The inscription in the centre of the seconds dial red, the rest black.

Steel hands, nicely finished and blued.

Movement

Dial plate diam. 101·9 mm; front plate diam. 82·4 mm; back plate diam. 82·4 mm; frame h. 24·4 mm.

Frame: Typical full plate construction with a detachable barrel bridge, four turned pillars, the back plate retained by blued steel screws. The dial plate a thick turned ring of brass with the front plate fitting into a recess and held by three blued steel screws in the dial plate. The brass parts are machine spotted. The escapement is mounted between a large potance screwed to the inside of the front plate and a disc let in flush in the back plate. The usual balance staff potance is dispensed with.

Fusee: Reversed fusee fitted with the usual stop-work and maintaining power. A dust-excluding tube made of a reddish brass is fitted over the winding arbor and secured to the back plate and there is a loose-fitting brass cap on the winding square.

The setting-up-work fitted on the barrel bridge, the arbor solid and unsnailed. The mainspring hooked with an eye at each end, and signed 'Geo. Cotton March 1893'.

Going train: Well made and finished to the usual English standard. The third arbor is shortened, and pivoted in the escapement potance and the front plate. The undercuts are very deep and well turned.

Jewelling: The fourth arbor pivot in the front plate bridge, and those of the escapement in pierced jewels. All the escapement jewels with endstones, a large diamond endstone, set in a blued steel ring, on the balance cock.

Escapement: Schoof's resilient lever with five-tooth brass escape wheel, jewelled polished steel pallet frame and resilient banking for a pin on the poising tail of the lever. All the lift is on the pallets whose impulse faces are concave. The pointed escape wheel teeth are also curved and show signs of wear. The lever, which is polished all over, has a pierced poising tail and transmits impulse to a D-shaped pin in the single roller. Safety action is achieved by a guard pin behind the fork notch and the polished edge of the roller. All the parts are very highly finished but are extremely heavily made and consequently have a high inertia.

Banking for the lever is by a pin in the tail against spring-loaded buffers in a frame on the underside of the back plate. If the amplitude of the balance becomes sufficiently great for the impulse pin to strike the back of the fork, the resilient banking gives and the train is slightly recoiled by a pallet pushing an escape wheel tooth slightly backwards. This protects the escapement from damage.

The reason Schoof gave for using a five-toothed escape wheel is that with fewer teeth than usual the energy losses due to drop are reduced for each turn of the wheel. The concavity of the pallet impulse faces and escape wheel teeth ends are more conducive to oil retention than the modern arrangement.

Balance: Bimetallic two-armed balance of the type invented by Victor Kullberg and called a Split Rim balance. The bimetallic rim section on each side of the crossbar is cut to make two portions of unequal length on the circumference. To the longer section is fixed two cylindrical brass weights held by screws on the inside. The shorter section is split by a wide slot into an upper and a lower portion. The lower portion is left with a web of metal running round to the crossbar so as to be very rigid and virtually unaffected by temperature. The upper portion carries a large brass screw set in the edge towards the free end. With a rise in temperature, the brass screw is carried towards the centre of the balance, but when the temperature falls below a certain value the section carrying the brass screw is banked against a screw set in the rigid section below. The other part of the rim, carrying the two cylindrical weights, functions in the ordinary way without interference. The weight nearer the free end carries a tangential steel screw to make small adjustments to the compensation. Diam. of rim 32·4 mm, h. 4·2 mm.

With a standard bimetallic balance and carbon steel spring there will be an increasing losing rate towards extremes of temperature if the rate at a middle temperature is correct. It will be seen that with the split rim balance more weight moves inwards with a rise in temperature from a middle value than moves out in cold. The effect is discontinuous, but owing to its great rigidity this balance gave good results, especially when used by Kullberg himself. This type of compensation is known as 'auxiliary compensation'. Apart from Loseby's balance (cat. no. 99), no really successful and theoretically correct solution to the problem of middle temperature error was found until Dr C. E. Guillaume introduced his nickel steel and brass bimetallic balance in about 1899 (see Appendix).

Balance spring: Blued steel helical spring of $11\frac{1}{2}$ turns, with terminal curves. The brass collet with a split counterpoising tail, the diamond-shaped brass stud attached to the balance cock with a single screw.

Going-train counts:
Great wheel (fusee) 90 teeth, $8\frac{1}{2}$ turns of groove
Centre pinion 14 leaves, wheel 90 teeth, 5 arms
Third pinion 12 leaves, wheel 80 teeth, 5 arms
Fourth pinion 10 leaves, wheel 120 teeth, 5 arms
Escape pinion 10 leaves, wheel 5 teeth, 5 solid teeth
Beats per hour: 7,200

Motion work:

Cannon pinion 14 leaves, minute pinion 18 leaves (brass)

Hour wheel 54 teeth, minute wheel 56 teeth

Up-and-down work:

Pinion on the fusee arbor of 10 leaves

Two wheels, one intermediate, each of 110 teeth, 5 arms

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of this chronometer from Todhunter in 1934. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-2070).

Exhibited: British Watches and Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954.

Note: After an adventurous early history (see below), the chronometer was purchased by the Admiralty in 1896, following the Greenwich trials of that year. The Admiralty purchased fifty-five chronometers on this occasion instead of the usual twenty or so, which was fortunate for Schoof as his chronometer had been placed fifty-fourth out of eight-three in the trials. It was the only one of his chronometers to be purchased by the Admiralty, but is reputed to have given good service at sea for many years.

When Schoof first brought out his lever escapement he made various claims for it that were criticised by T. D. Wright, Sir Edmund Beckett, later Lord Grimthorpe, and Robert Gardner. A positive result of this was the friendship that developed between Schoof and Gardner which led to the latter making the final adjustments to this chronometer. Schoof was fortunate to secure the help of so able an adjuster who, in 1897/8, won the Greenwich trials with his number 5/4162 against Victor Kullberg and Johannsen and Co.

The following story, told to C. A. Ilbert by A. W. Curzon in 1949, is recorded on a typed sheet preserved with a photograph of Schoof (1830–1901) and various trade cards, with the chronometer:

> *Schoof Lever Escapement*
>
> Schoof apparently made two of his five toothed 'scape wheel lever chronometers. One he left to Gardner and the other just managed to obtain a place in the Greenwich trials on an occasion when more chronometers than usual were bought. The Greenwich Schoof was stolen from 99 St. John's Street Road in about February 1889. The thief took at the same time a box of cigars, a few chronographs and Mr. A. W. Curzon's spectacles. Nothing was heard of the chronometer for approximately eight months. At that time a policeman patrolling the Mile End Road saw a known scamp carrying a parcel under his arm and stopped him, as a matter of principle, to examine it. The man stated that it was, 'Only an old clock'. Even the policeman was able to see that it was something rather more. The Police Station asked the local pawnbroker for his opinion of the value of the piece. They were told that it was worth £80, and the man further advised them to get in touch with the Horological Institute with a view to the possibility of their having some knowledge of a missing chronometer. Britten was able to identify the chronometer as Schoof's and it was returned to him. The name had been stoned off the potance plate, which in consequence was made very much thinner. As a result, the balance staff was too long and visiting cards had been placed underneath the cock to allow end shake. Schoof eventually re-finished the chronometer and sent it to Greenwich with the results that are well known. The receiver of the chronometer was sent to prison for eight years. It transpired that the chronometer would have, if it had not been recovered, been placed in a ship which was sailing the same day at 4 p.m. The receiver was in fact on his way there. No action was taken against the thief as it turned out that he was already doing penal servitude at Dartmoor. The police asked Schoof his estimation of the value of his chronometer and he said that he did not reckon that it was more than about £20. The police, however, told him that they particularly wished to prefer a substantial charge against the receiver, and Schoof, to oblige them, then stated that he valued the piece at £80.

Schoof also had one of his chronometers tested in Switzerland.

Bibliography: Bertele 1981, p. 265; Chamberlain 1941, pp. 457–8; Gould 1923, pp. 152–4.

142 L. LEROY ET CIE.

(Louis Leroy 1859–1934)

c. 1900

DECK WATCH WITH LEVER ESCAPEMENT

Plates 103e–f, 104a–b

Signature: On the back plate and dial 'L. Leroy & Cie N° 1763'. On the inside of the front plate 'N° 1763'.

Case: Heavy open face plain silver case numbered 1763 on the inside of the cuvette and back, and with various punch marks inside the back including L. Leroy's monogram of entwined 'L's in a square cartouche. In a diamond-shaped cartouche the letters S.G. flanking a key and surmounting a five-pointed star. The middle and both back and cuvette also have a quality control mark of a crab in a five sided cartouche.

The outside of the back engraved in large letters with the inscription in capitals 'SERVICE HYDROGRAPHIQUE DE LA MARINE L. LEROY & CIE N° 1763'.

The outside of the cuvette engraved with the inscription 'L. Leroy et Cie 13–15 G$^{\underline{\text{RIE}}}$ MONTPENSIER PARIS'.

The glazed front bezel snapping onto the middle. The back and cuvette hinged to the middle with three poorly made knuckle joints. The pendant with a heavy ring, and a silver winding button, and to one side an olivette for setting the hands. Diam. 59·9 mm, overall h. 19·1 mm.

Dial and hands: Flat enamel canister dial with sunk subsidiary seconds with a positioning peg.

Blued steel spade hands, seconds hand probably not original.

Movement

Ebauche marks 56·2 over 1763, 4.

Front plate diam. 49·8 mm; back plate diam. 48·0 mm; frame h. 7·9 mm.

Frame: Three-quarter plate built up from two thick plates, the back plate recessed to leave room for the balance and escapement pivoted on the front plate under separate cocks. The front plate recessed for the keyless and motion work and with a separate bridge for the barrel lower bearing. All the brass parts gilded. The movement secured by two dog screws and positioned by a peg.

Barrel and keyless work: Going barrel with five-turn Geneva stop-work on the cover end. The mainspring fitted with a bride passing into slots in the cover and bottom of the barrel near the outer hooking of the spring. Typical sliding pinion keyless work, the hand set operated by a push-piece in the case middle near the pendant. Mainspring dimensions: 3·80 mm × 0·20 mm, for a barrel diam. of 19·0 mm, 1963 marked on the spring.

Going train: Typical layout and construction, the brass wheels gilded, the steel pinions and arbors well finished and polished. The centre pinion hollow for the arbor carrying the cannon pinion.

Jewelling: The pivots of the centre, third, fourth and escapement arbors in fine large jewels, those of the escapement all with rubbed in endstones. The train jewels *bombé*.

Escapement: Club-tooth lever escapement with double roller on the balance staff, and poising tails screwed to the fork. The steel escape wheel of heavy construction with an unusually wide rim. The steel dart screwed to the underside of the fork.

Balance: Bimetallic two-armed balance, the arms of sage-leaf pattern, with gold screws and one pair of platinum screws at the free ends of the rim.

Balance spring: White metal spiral spring, probably made of palladium, with an overcoil and terminal curve. Palladium balance springs were introduced by Paillard in 1880 and used in precision watches to reduce the middle temperature error. They were also used because they were rustless and non-magnetic, and continued to be used even after the introduction of the Guillaume balance because of these two advantages.

An index is fitted on the balance cock and a steel plate with two screws to clamp the stud.

Going-train counts:
Great wheel (going barrel) 90 teeth
Centre pinion 14 leaves, wheel 96 teeth, 5 arms
Third pinion 12 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Keyless work:
Crown wheel 22 spur teeth, 13 ratchet teeth
Castle wheel 26 spur teeth, 13 contrate teeth
Intermediate winding wheel 45 teeth
Barrel ratchet wheel 49 teeth
First intermediate hand set wheel 24 teeth
Second intermediate hand set wheel 28 teeth

Provenance: Ilbert Collection; purchased by Ilbert in 1932 from Moran of Clerkenwell (reg. no. CAI-1130).

143 probably VICTOR KULLBERG
c. 1900

KEYLESS GOING BARREL LEVER WATCH MOVEMENT WITH CHRONOGRAPH *Plates 104c–f, 105a*

Signature: On the back plate ‘Army & Navy Cooperative Soc^{ty} L^{d} 105 Victoria Street LONDON S.W. Nº 6546’.

Case: No case, but was open face.

Dial and hands: Flat enamel dial with sunk subsidiary seconds and minute recording dials, inscribed ‘6546’. The outermost circle with divisions of fifths of seconds, encircling a ring of minute divisions. Canister dial with a positioning peg.

Movement
Ebauche marks 16 × 0 over 6546.

Front plate diam. 44·8 mm; front plate th. 3·9 mm; back plate diam. 43·0 mm; frame h. 8·5 mm.

Frame: Half plate construction with three turned pillars, the back plate retained by blued steel screws, and having a raised portion over the going barrel. The front plate deeply hollowed under the dial to accommodate the chronograph work, keyless work, motion work and a separate plate with the lower third, fourth and escapement bearings. On the back of the front plate, the escape and pallet upper bearings are carried in a bridge as used by the firm of Victor Kullberg (see also Victor Kullberg, cat. no. 136).

Going barrel and keyless work: The going barrel is fitted with a five-turn Geneva stop-work on the cover end. The stop-piece finger is squared to the barrel arbor and retained by a steel disc also squared to the arbor and formed to a pivot and shoulder working in the back plate. Neither the barrel nor its cover is gilded, both are decorated with snailing. Typical English rocking-bar keyless work is fitted.

Going train: Conventional layout and construction, the brass wheels gilded, the steel pinions and arbors well finished and polished. The centre arbor hollow for the cannon wheel arbor secured by a polished steel nut.

Jewelling: The pivots of the centre, third, fourth and escapement arbors run in pierced jewels, those of the escapement with endstones. A diamond endstone in a blued steel ring is fitted on the balance cock. The train jewels *bombé*.

Escapement: Ratchet-tooth lever escapement, the wheel and pallet centre line at right angles to the fork and roller centre line. The polished steel double roller and fork with gold dart resemble those fitted in cat. no. 136 by Victor Kullberg except the jewel impulse pin is D-shaped.

Balance: Bimetallic two-armed balance with gold screws and quarter nuts. Diam. 17·5 mm, h. 0·8 mm.

Balance spring: Blued steel spiral spring with 15 tight coils, with an overcoil and terminal curve, free sprung to a diamond-shaped polished steel stud on the balance cock, and a polished steel solid collet with two flats for adjusting on the balance staff.

Chronograph mechanism: Instantaneous minute recording chronograph, the action controlled by a pillar wheel and a series of levers pivoting on pillars each with its individual return spring. The whole of this mechanism is fitted on the front plate under the dial and operated by a single push-piece at the pendant. The drive for the chronograph is taken from the fourth wheel via a jockey wheel in permanent mesh with the fourth. Mounted on the same arbor as the jockey wheel is a steel wheel having fine teeth on its edge, corresponding with those of a brass wheel at the centre carrying the chronograph centre seconds recording hand. The jockey wheel is caused to move towards or away from the central seconds recording wheel by the pillar wheel acting on the other end of the bar on which it is pivoted. This makes or breaks the transmission between the fourth wheel and the centre.

Fitted on the same arbor as the minute recording wheel are two cams, one for the return to zero of the seconds hand, the other to raise a lever and exactly at the minute, as shown by the seconds hand, allow the lever to fall and advance the minute recording wheel and hand by one minute. This is the most accurate system devised for advancing the minute recording hand as nearly as possible to the minute. It is intended to avoid the confusion that can exist when the seconds recording hand has been stopped at or near the minute and there is uncertainty as to whether the corresponding minute has been recorded by the other hand. If carefully made and adjusted the minute recording hand can be made to advance during the last fifth of a second before the beginning of the next minute as shown by the seconds recording hand.

Going-train counts:
Great wheel (going barrel) 92 teeth
Centre pinion 14 leaves, wheel 96 teeth, 6 arms
Third pinion 12 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon wheel 35 teeth, minute wheel 35 teeth
Hour wheel 96 teeth, minute pinion 8 leaves

Keyless work:
Central rocking bar wheel 54 teeth
Winding rocking bar wheel 34 teeth
Hand set rocking bar wheel 23 teeth
Barrel ratchet wheel 64 teeth
Intermediate hand set wheel 14 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1933 (reg. no. CAI-908).

144 probably VICTOR KULLBERG

c. 1909

KEYLESS FUSEE LEVER WATCH *Plate 105b–d*

Signature: On the back plate: 'Army and Navy Co-operative Society Ltd., 105 Victoria St. LONDON, S.W. No 9019'.

Case: Open face 18-carat gold case with the London hallmark for 1909 and the maker's mark FT in a lozenge over LONDON, under the whole A, indicating that the case was made by Arthur Bamford in the workshop of Frederick Thoms. The cuvette and back are hinged to the middle and both have the punched number 9019. The swivelling pendant is hollow for the winding arbor with integral pinion at the inner end. The other end of the arbor carries the gold-covered winding button on a squared portion, held by a small nut.

Dial and hands: Flat enamel canister dial with sunk subsidiary seconds and up-and-down dials, no positioning peg has been provided for this. The back of the dial is not signed, and three copper feet have been cut off and filed flush with the backing enamel. Inscribed '9010'.

Blued steel hands.

Movement
Ebauche marks 12 × J.P. (Joseph Preston) over 9019.

Front plate diam. 41·3 mm; back plate diam. 39·4 mm; frame h. 7·2 mm.

Frame: Typical half plate construction with three turned pillars, the back plate retained by recessed blued steel screws. The frame is very similar to that of cat. no. 136 by Victor Kullberg, note especially the bridge over the escape wheel and pallets, the general layout and the shape and position of the various turned recesses in the front plate. All the brass parts gilded.

Fusee: Reversed fusee with the usual stop-work and maintaining power with steel maintaining ratchet wheel. The setting-up work fitted in a recess on the dial side of the front plate, the barrel arbor with an extended square on that end only. The fusee arbor squared at the back even though keyless work is fitted, the squared arbor for the convenience of the watchmaker. The barrel with a flange on the cover end.

Going train: Typical layout and construction with a reversed fusee, the fourth wheel above the third, the centre arbor hollow for the hand-set arbor carrying the cannon pinion. The brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: All the pivots of the going train, including the fusee, run in finely-made pierced *bombé* jewels made of natural ruby. The escapement arbor and balance staff pivots in pierced jewels with endstones, a diamond endstone set in a blued steel ring is fitted on the balance cock.

Escapement: Right-angled ratchet tooth lever escapement very similar to that of cat. no. 136. The dart appears to be made of gold and is held by a screw and steady pin to the underside of the fork. The round impulse pin on the polished steel double roller is of clear sapphire and has a small flat facing outwards. The quality of the finish throughout is of the very highest order.

Balance: Bimetallic two-armed compensation balance with gold screws and quarter nuts. Diam. 17·3 mm, h. 1·6 mm.

Balance spring: Blued steel spiral spring of $18\frac{1}{4}$ turns, with an overcoil and terminal curve, free sprung to a polished steel diamond-shaped stud on the balance cock. The collet of polished steel with two flats and a single slot to spring it onto the balance staff.

Kullberg fusee keyless work: Very similar to that fitted to cat. no. 136 and fully described in that entry. The only difference is that the steel bevel wheel engaged by the pinion on the end of the winding arbor is held by a plate with three screws to prevent it turning, instead of a single screw and locking pin.

Going-train counts:
Great wheel (fusee) 84 teeth
Centre pinion 14 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 72 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 3 arms
Beats per hour: 16,200

Motion work:
Cannon pinion 16 leaves, minute pinion 8 leaves
Hour wheel 48 teeth, minute wheel 32 teeth (steel)

Keyless work:
Winding arbor pinion 21 leaves
First rocking bar wheel with bevelled teeth, 45 teeth
Second rocking bar wheel 30 teeth
Wheel threaded on the fusee arbor 56 teeth
Intermediate hand-set wheel 16 teeth

Up-and-down work:
Pinion on the fusee arbor 12 leaves, wheel carrying the indicator hand 72 teeth

Provenance: Bequeathed by Mr F. R. S. Rogers in 1972 (reg. no. 1972, 9-3, 8).

145 PAUL DITISHEIM

c. 1915

KEYLESS GOING BARREL LEVER DECK WATCH

Plates 105e–f, 106a–c

Signature: On the back plate 'Paul Ditisheim La Chaux-de-Fonds. The Highest Records at Kew, Teddington and Swiss Observatories. 46870 COMPENSATEUR GUILLAUME I$^{\text{ERE}}$ CLASSE SWISS MADE'.

Also signed on the dial 'Paul Ditisheim LA CHAUX-DE-FONDS GRAND PRIX PARIS 1900'.

Case: Silver case, with the Swiss quality control mark 0·935. The glazed front, cuvette and back snapping onto the heavily reeded middle. Threaded caps with leather washers over the winding button and hand-set push-piece. The back of the case engraved 'Kew Observatory 95·4 marks, H.R. B' and in a circular cartouche 'Paul Ditisheim Compensateur Guillaume 46870'. The inside of the cuvette and back both also marked 'Paul Ditisheim Fabricant 46870'. Diam. 64·8 mm, overall h. 23·3 mm.

Dial and hands: An engraved silvered flat brass canister dial. Two screws pass through the dial and ring, and into blocks set inside the middle of the case. The figures printed on the surface, some of the divisions previously engraved or marked under the black paint. Subsidiary dials for seconds and reserve of going indicator. The dial inscribed 'Paul Ditisheim LA CHAUX DE FONDS GRAND PRIX PARIS 1900' and '46870'. On the back is punched 46870 and scratched 4602.

Blued steel spade hands.

Movement
Ebauche marks 46870 on the dial plate. Several of the parts punched 4.

Front plate diam. 56·0 mm; back plate diam. 53·8 mm; frame h. 10·6 mm.

Frame: Three-quarter plate construction, with the plates recessed to accommodate the wheels, and under the dial to leave room to lodge various bridges and cocks. The movement a tight fit in the case middle, and with three positioning pegs, secured by two screws through the edge of both the dial and the dial plate and into blocks set inside the case middle. The flange on the edge of the front plate is thus sandwiched between the dial plate and the case middle and very securely held. All the brass parts gilded.

Keyless work and going barrel: Swiss sliding pinion keyless work, with the hand set operated by a push-piece in the pendant. The intermediate winding wheel lodged on the inside of the back plate with the barrel click and return spring. The barrel ratchet wheel integral with the threaded barrel arbor onto which screws the snailed central portion to which the inner end of the mainspring is hooked. This arrangement allows greater height within the frame for a given thickness of movement, and particularly a higher thinner mainspring.

Geneva stop-work was originally fitted on the cover end of the barrel but is now missing. Mainspring dimensions: 5·00 × 0·24 mm for a barrel diam. of 23·0 mm.

Up-and-down work: Operated by a spherical differential between the great wheel and the winding ratchet wheel. There is an intermediate wheel between the barrel ratchet wheel and the first wheel on the differential arbor. The pinion on the end of the differential arbor under the dial drives a wheel on the arbor of a pinion driving the wheel carrying the indicator hand. For a full description of the principle on which this type of mechanism functions see *Britten's Watch and Clock Makers Handbook*, 16th edition, ed. R. Good, p. 330.

Going train: The wheels remarkably small for so large a movement. Square-bottomed tooth forms are used for all the teeth and leaves, except those of the great wheel and centre pinion which are round bottomed. The teeth of the great wheel extend about half way up the side of the barrel. The brass wheels are gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the centre, third, fourth and escapement arbors are run in pierced jewels, those of the escapement with endstones. The *bombé* train jewels in the back plate are large and well made, and set in brass rings held by blued steel screws.

Escapement: 'In line' club-toothed lever escapement of very high quality. The steel escape wheel sunk out on both sides to leave only the tips of the teeth the full thickness. Both the top and the bevelled edges of the steel pallet frame highly polished, as well as the dart, which is secured by a screw on the underside. The pallet stones, apparently of natural ruby, have both top and bottom surfaces bevelled and polished and both impulse planes are slightly concave in the plane of the escape wheel. A double polished steel roller made in two separate parts, the impulse pin a D-shaped piece of ruby set at a large radius from the balance centre.

Balance: Bimetallic two-armed balance of Guillaume type, in which the steel part is made of a special iron/nickel alloy containing about 44% nickel to reduce the secondary error of compensation to a very small value. The compensation screws appear to be of red gold and are chamfered on the underside to prevent rim distortion. The arms join the rim about half way up the rim. Rim h. 1·825 mm, diam. 20 mm, diam. over screws 22·5 mm.

Balance spring: Blued steel spiral spring of slightly less than 12 turns with an overcoil and terminal curve, there is no inner terminal curve to the collet. The point at which the balance spring is pinned in at the collet is on a line parallel to the centre line of the watch through the pendant, and on the pendant side. Due to the effect of gravity on the spring this will produce a slight advance in the pendant left position, have no effect in pendant up or pendant down and will produce a slight retard in the pendant right position. The small diameter round the brass collet has two flats for adjusting, clear of the spring. A polished steel diamond-shaped stud is fitted on the balance cock, with an index, both are similar to those often used by the British watchmaking industry.

Going-train counts:
Great wheel 124 teeth
Centre pinion 12 leaves, wheel 96 teeth, 5 arms
Third pinion 12 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 80 teeth, 5 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Keyless work:
Crown wheel 29 spur teeth, 13 ratchet teeth
Castle wheel 22 contrate teeth, 13 ratchet teeth
Intermediate winding wheel 52 spur teeth, 46 contrate teeth
Barrel ratchet wheel 64 spur teeth
First intermediate hand-set wheel 17 teeth
Second intermediate hand-set wheel 31 teeth

Provenance: Bequeathed by Mr F. R. S. Rogers in 1972 (reg. no. 1972, 9-3, 11).

Bibliography: Norbert Eder, *Beobachtungsuhren* Munich, 1987, frontispiece and pp. 124, 125; *Le mètre et la seconde, Charles-Edouard Guillaume (1861–1938)*, Musée international d'horlogerie, La Chaux-de-Fonds, 1988.

146 PAUL DITISHEIM SOLVIL

c. 1930

KEYLESS GOING BARREL TIMEPIECE

Plates 106d–e, 107a

Signature: On the dial 'SOLVIL PAUL DITISHEIM'. On the front plate numbered under the dial and on the barrel bridge '720856'.

Case: Bright stainless steel case with glazed front bezel, and cuvette and back hinged to the middle. Signed inside the back in a cartouche 'Solvil Paul Ditisheim' and numbered 481237, also on the cuvette with larger cartouche and reproductions of six medallions and 'GRAND PRIX PARIS 1900–BERNE 1914', and numbered on the inside 481237. Diam. 49·0 mm, h. over glass 13·0 mm.

Dial and hands: Enamel dial with sunk subsidiary seconds and up-and-down indicator, the centre also sunk, retained by two feet and screws in the edge of the front plate. The back of the dial marked '405 s' in the enamel.

Blued steel moon hands.

Movement

Ebauche marks on the front plate, under the dial 'Solvil'.

Front plate diam. 42·8 mm; front plate th. 2·85 mm; frame h. 5·2 mm.

Frame: Rhodium-plated brass frame with brightly polished steel screws.

Going barrel: Thirty-six hours reserve of going, no stop-work. Swiss positive keyless work. Recoiling click and spring under the barrel bridge.

Up-and-down indicator: Driven by a spherical differential between the teeth of the intermediate winding wheel and those of the going barrel.

Going train: Gilded brass wheels, the cannon pinion a snap-on friction fit on the extended centre arbor.

Jewelling: The centre arbor rear pivot in a flat pierced jewel. The pivots of the third, fourth and escapement arbors in pierced *bombé* jewels. The balance staff pivots in fine pierced jewels with endstones. All the jewels rubbed in.

Escapement; Swiss club-toothed lever escapement with divided lift. Steel escape wheel and jewelled double roller, brass pallet frame with jewelled pallets.

Balance: Gilded brass uncut balance with two short brass and steel bimetallic affixes for residual compensation, the steel on the outside the brass on the inside, invented and first used by Paul Ditisheim, each fixed to the outside of the rim near the end of the arm. Diam. 16·9 mm, h. 0·9 mm.

Balance spring: Early elinvar spiral spring with overcoil and terminal curve pinned to a steel stud on the balance cock. Geared index for fine regulation.

Going-train counts:
Great wheel (barrel) 90 teeth.
Centre pinion 12 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute pinion 36 teeth

Note: The firm of Solvil was founded in the early 1920s to exploit Paul Ditisheim's invention of the 'affix' balance with an elinvar alloy balance spring. The purpose was to make fine precision pocket watches more cheaply than those fitted with a Guillaume balance. In the course of time, much to Paul Ditisheim's grief, commercial considerations began to outweigh those of quality, and as all his efforts to bring about improvement failed, he resigned from the board of the company in 1929. In spite of this his name continued to be used for publicity purposes, though he repeatedly denied any association with the company. See Professor D. S. Torrens' tribute to Paul Ditisheim, *H.J.*, December 1945.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1938 (reg. no. CAI-1198).

II.ix (cat. nos 147–164)

UNUSUAL ESCAPEMENTS FOR PRECISION USE

This group comprises timekeepers with unusual escapements that are not of a constant force variety. These escapements were not made in any quantity.

THE PETTO CROSS DETENT

An interesting variant of Arnold's and Earnshaw's escapements is the 'cross detent' invented by James Petto in about 1783. It is not known if Petto intended to combine the advantages of Arnold's and Earnshaw's escapements or altered their escapements merely to circumvent the patents protecting them. In Petto's design the detent and passing spring are separate and on opposite sides of the balance, and the detent is held in tension as in John Arnold's escapement (see figs 9 and 9a). Impulse is given to the balance in the same way as in Thomas Earnshaw's escapement, but at the expense of a heavier detent. The extra mass is at the free end, and this will increase the likelihood of the detent bouncing against its stop, or unlocking at the wrong moment, following an external shock to the watch. There is also a frictional loss caused by the relative motion of the nose of the detent and the passing spring, and if both are made of steel there must be oil at this point. Most of the very few surviving examples of this escapement are in watches signed Brockbanks, for whom James Petto worked. The detents are remarkably heavy and cumbersome and with the passing spring occupy the entire diameter of the back plate, even in marine chronometers. Breguet was able to refine and lighten the detent and made a number of successful examples of the escapement as the Arnold/Breguet tourbillon, cat. no. 176, so clearly demonstrates. Where the detent has to be very small or under some additional pressure the escapement has an advantage and this is the case in a tourbillon.

THE DETACHED VERGE ESCAPEMENT

The horologist who devised, improved and investigated more escapements than anyone is undoubtedly A. L. Breguet. His apparently innate sense of correct proportions and mechanical principles enabled him to take escapements, such as the lever and the cylinder, devised by others and improve them dramatically. His own escapements, such as the 'échappement naturel' in one or other of its form or his type of constant force, evoke the greatest admiration for their ingenuity. That in cat. no. 152 has been described by Daniels in *Breguet* (1975) as a vertical wheel natural lift escapement and is, in fact, a type of detached verge.[1]

ROBIN ESCAPEMENT

The other watch in this section, by Breguet (signed *Breguet et fils no. 36*) has a Robin escapement. The lever and pallet system are remarkably heavy and cumbersome, and there are signs of alteration. It is not known what Breguet wished to discover from this particular example. In this escapement there is a lever which effects unlocking only, impulse being given directly by the escape wheel to the balance as in the chronometer escapement. Very few escapements have successfully rivalled the lever or the detent for precision use.

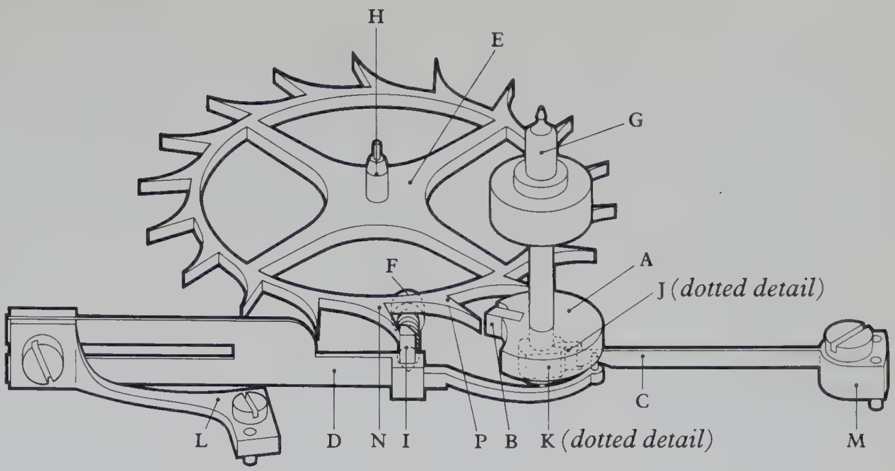
THE PATENT UNION CHRONOMETER

This chronometer has an escapement in which impulse is given as in a Robin, the duplex escape wheel is locked by lever pallets and unlocking of the escapement is carried out in a similar way to a duplex (see figs 10 and 10a). Another variant, the Union Patent Chronometer, achieves similar results with a single set of escape wheel teeth. The advantage of such an arrangement is that the unlocking is very light and impulse is given in a favourable way across the line of centres joining the balance and escape axis. In the patent, No. 2184 (taken out in 1863), Kelvey and Holland of Birkenhead claimed that the escapement prevents setting, and that impulse is given at the lever by unlocking. Its disadvantage is that it is a frictional rest escapement and needs oiling at the ruby roller, and so is little better than the duplex. It is interesting to note that the first four watches in this series, three patent union chronometers and one union patent chronometer, all have the same ébauche mark '*H.F.*' The next watch in the series, signed *R. Thompson*, *London Patent Chronometer*, also has an ébauche by 'H.F.' This is possibly Henry Fletcher of Prescot who is listed under Movement Makers in the Post Office *Directory* for 1872. The London Patent Chronometer has an escapement that is a revival of the Robin in which the lever is used for locking and the escape wheel gives impulse on alternate beats as in a

FIGURE 9

James Petto's cross detent escapement

A	impulse roller
B	impulse jewel
C	discharge detent
D	passing detent
E	escape wheel
F	banking screw
G	balance staff
H	escape wheel pinion
I	locking stone
J	discharge jewel
K	discharge roller
L	detent foot
M	cross detent foot
N	escape wheel tooth
P	escape wheel tooth



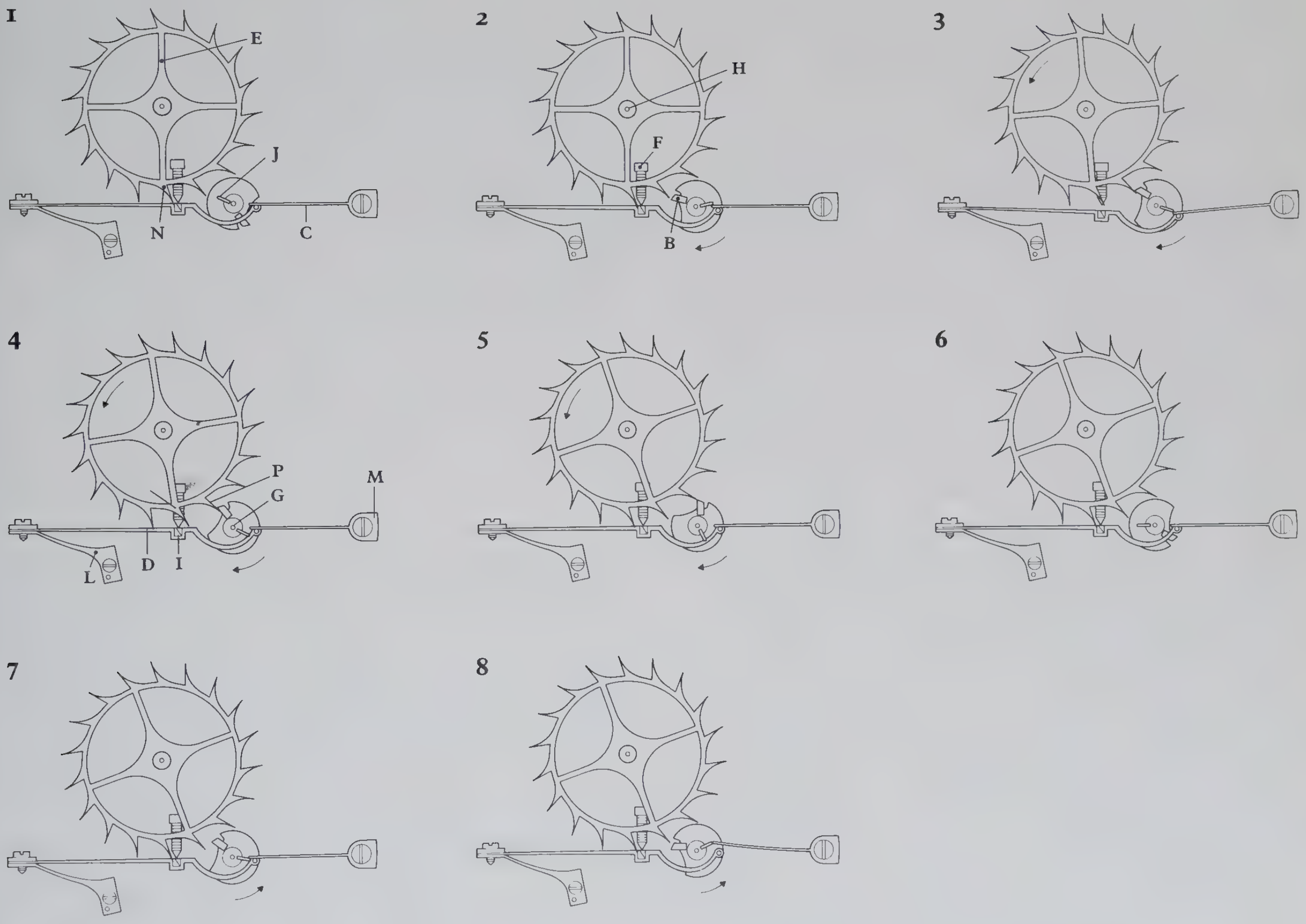


FIGURE 9A

Sequence of operations of James Petto's cross detent escapement

1 Escape wheel E locked
2 Discharge jewel J picking up passing spring C
3 Detent D moved aside by passing spring C unlocking wheel tooth
4 Impulse occurring
5 Impulse about to end
6 Wheel E locking again
7 Reverse swing of balance, discharge jewel pushing aside passing spring with no action resulting
8 Discharge jewel about to leave passing spring

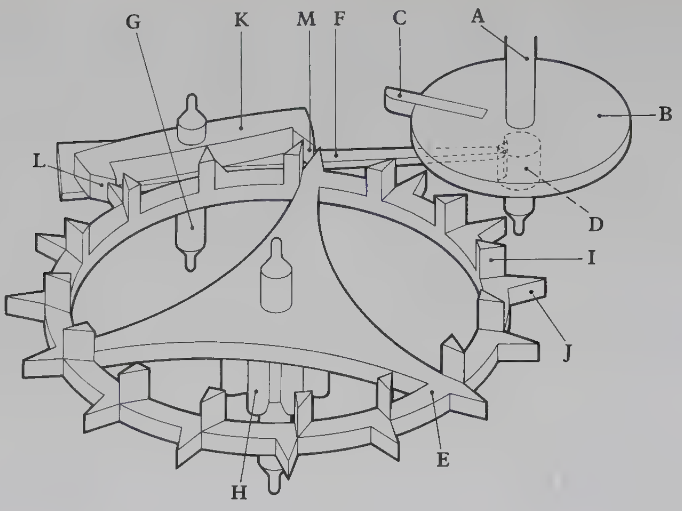


FIGURE 10
Patent Union escapement

A	balance staff
B	impulse roller
C	impulse jewel
D	ruby roller with notch
E	escape wheel
F	pallet arm
G	pallet staff
H	escape pinion
I	impulse tooth
J	locking tooth
K	pallet body
L	entrance pallet
M	exit pallet

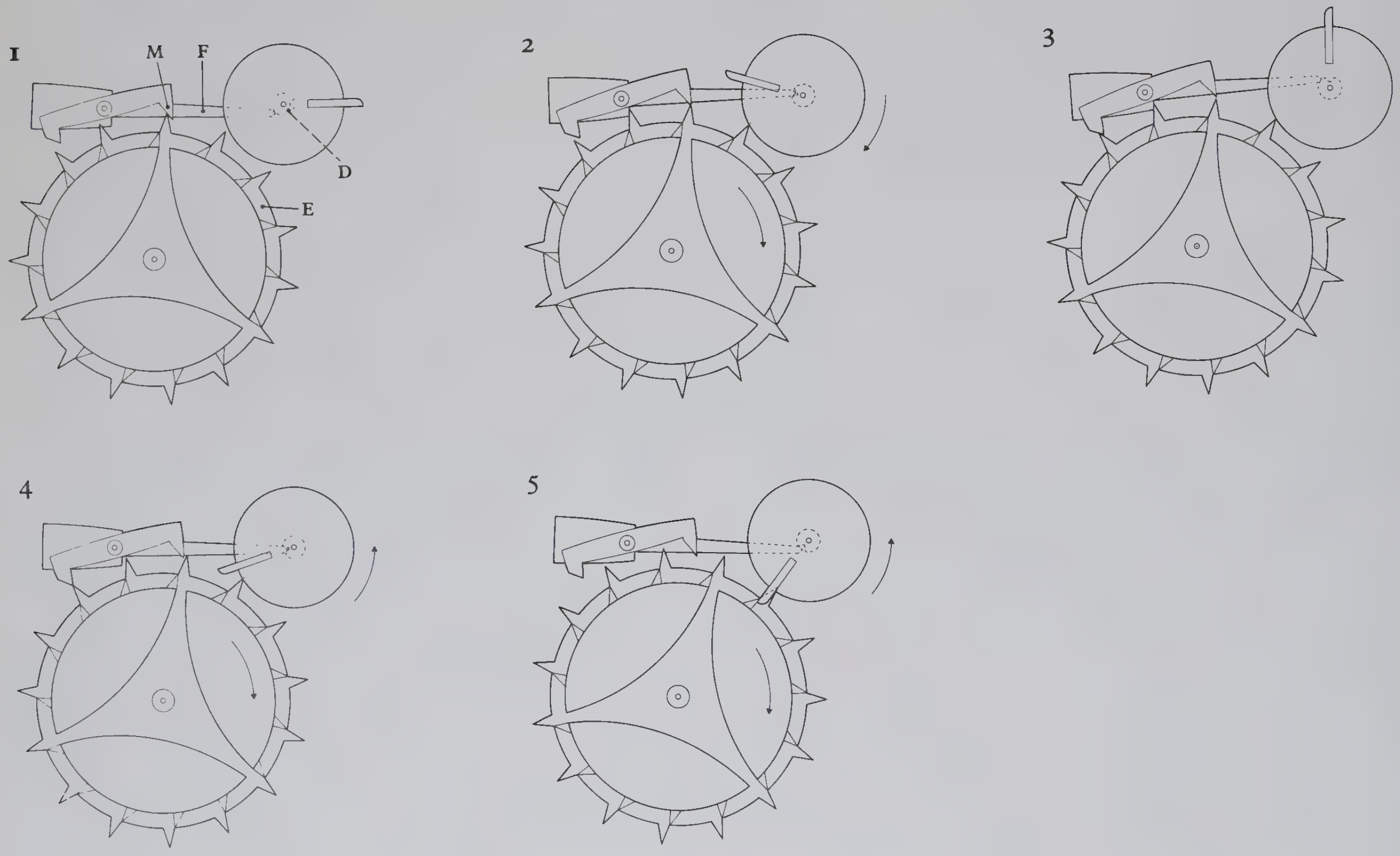


FIGURE 10A
Sequence of operations of Patent Union escapement

1 Balance about to return in clockwise direction. Lever biased against passing roller
2 Escape wheel being unlocked as notch in passing roller allows lever to move over
3 Balance about to return in anticlockwise direction, lever biased against passing roller again
4 Unlocking occurring as balance continues to move in anticlockwise direction, impulse about to be given
5 Impulse being given by upstanding teeth of escape wheel

chronometer. The balance is required to drive the lever and unlock the train via the pallets at each swing, and impulse is only given on each alternate swing. This is mechanically less efficient, and causes a greater disturbance to the balance than either the lever or the detent.

MISCELLANEOUS ESCAPEMENTS

Another, Pritchard's patent chronometer, has a form of pivoted detent escapement without the usual light spring to hold the detent against its banking. The function normally carried out by this spring is performed by the balance, thus introducing increased friction and disturbance where these are least desirable. Charles Fasoldt, an American maker, also invented an original escapement which unfortunately suffered from very low mechanical efficiency, which is evidenced by the excessively strong mainspring required. The balance is required to drive a lever and pallet system to unlock one escape wheel, and impulse is transmitted at alternate beats, through the lever, by a second escape wheel on the axis of the first. This is a combination of lever, Robin and duplex escapements, the only advantage being that it does not need to be oiled.

Of the examples in this section thirteen have fusees, the remaining five, cat. nos 151, 152, 153, 161 and 162, have going barrels.

Note

1. Daniels 1975, pp. 314–17.

147 BROCKBANK
c. 1785

CHRONOMETER *Plates 107b–f, 108a–b*

Signature: On the barrel bridge in characteristic script 'Brockbanks', and 'LONDON' and 'No 383'.

Case: Silver consular case with the London hallmark for 1781 and maker's mark J.D. The case appears to have been made before the movement, the latter with its cross detent escapement could not have been made before 1785. Diam. 68·8 mm, overall h. 29·0 mm.

Dial and hands: Flat enamel dial attached to the dial plate by short feet and pins. The rings and markings for minutes and seconds appear to have been marked directly on the dial with a diamond point without any prior marking.

Steel hands, the minute hand a replacement.

Movement

Dial plate diam. 60·9 mm; front plate diam. 57·3 mm; back plate diam. 55·9 mm; frame h. 10·5 mm.

Frame: Similar to cat. no. 150.

Fusee: Keywind fusee with stop-work and maintaining power with a brass ratchet wheel. The setting-up-work of blued steel under the dial on the front plate. The maintaining detent and its return spring screwed to the inside of the front plate of blued steel. The barrel arbor with an extended square at both ends. Scratched on the dial plate 'Leah 1836–2'.

Jewelling: The pivots of the third, fourth and escapement arbors run in pierced jewels, the escapement with endstones. The third and fourth jewels on the back plate made of very large clear white sapphires and very well polished.

Escapement: Similar to cat. nos 149 and 150. Peto cross detent escapement with very highly polished steel escape wheel, the leading edges of the teeth only slightly raked forward. Steel passing spring. The detent has been repaired by the substitution of a new foot and spring blade, crudely made and soldered to the original detent. The gilding on both sides of the back plate, particularly on the inside, has been damaged. The locking stone is a replacement made of steel. Usual jewelled and polished discharge roller. The steel impulse roller with only the edge polished and with a jewelled pallet leaning towards a radial to the tip, which has resulted in slight damage to the leading edges of the escape wheel teeth.

Balance: Similar to cat. no. 150 except that the brass segment weights are secured by steel screws only and that the pieces limiting the travel of the free ends (in both directions) of the bimetallic rims are integral with the arms. The steel stud on one of the arms that once acted with the amplitude limiting device still present. Diam. of rim 25·2 mm, h. 1·7 mm.

Balance spring: Blued-steel helical spring of $3\frac{1}{2}$ turns with terminal curves, the upper one rather short and attached to a screwed block on the overhanging adjustable stud. The lower terminal curve pinned with a half-round pin to a poised steel collet. There was once an amplitude limiting device similar to that fitted to cat. no. 150 mounted on the barrel bridge, the holes for which are still visible, one filled with a small screw.

Balance cock: All the upper surfaces heavily engraved.

Going-train counts:
Great wheel (fusee) 80 teeth, badly worn
Centre pinion 16 leaves, wheel 90 teeth, no crossings
Third pinion 12 leaves, wheel 80 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth, 6 arms

Motion work:
Cannon pinion (snap on) 14 leaves, minute pinion 18 leaves
Hour wheel 54 teeth, minute wheel 56 teeth

The polished steel minute pinion on a tube on the minute wheel.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1952 (reg. no. CAI-1723).

Note: For another example of a marine chronometer by Brockbanks with a Peto cross detent see cat. no. 601 in the Collection of the Worshipful Company of Clockmakers. It is dated about 1785.

Bibliography: *Catalogue of the Collection of the Worshipful Company of Clockmakers*, London, 1975, p. 99.

148 BROCKBANK

c. 1800

MARINE CHRONOMETER *Plate 108c–d*

Signature: On the dust cover 'Brockbank's LONDON No 436'. On the dial 'BROCKBANKS LONDON'.

Box: Octagonal mahogany box with a glazed hinged lid, a lock and fixed raised carrying handles. The handles are each drilled for a gimbal ring pivot. At the front of the box is an inset ivory disc faintly inscribed 'Brockbanks 436', held by two countersunk brass screws. The domed glass is secured under a turned brass bezel. The movement itself is protected by a brass drum fitting with a bayonet catch on the dial plate. There is a winding hole in the bottom of the drum and another in the bottom of the box protected by a rotatable escutcheon plate with offset hole. The dial plate fits in a recess in an octagonal board and is held by two clips pivoted on screws on the edge of the box which can be swung and clamped under screws standing proud of the dial plate. There is also provision to fix the dial plate to the board by three equally spaced screws passing through the board and into the dial plate. The bottom of both box and lid are covered with green material glued on. Box 161 mm across the flats, h. 90 mm excl. bezel.

Dial and hands: Enamel dial with three short feet passing through holes in the dial plate and secured by eccentric screws. The divisions on the dial are engine divided under the black enamel. There is no reserve of going indicator.

Blued steel spade hands, flat on their upper surfaces.

Movement

Dial plate diam. 132 mm; front plate diam. 103·6 mm; back plate diam. 103·3 mm; frame h. 27·9 mm

Frame: Massive full plate construction with four turned pillars, the back plate retained by relatively small blued steel screws. There is no detachable barrel bridge. The general appearance is similar to that of Barwise No. 4307, cat. no. 91, though the pillars are tapered and not baluster. The dial plate, into which the front plate fits flush is secured by three equally spaced screws in the edge, is lacquered. There is a separate bridge on the front plate for the third, fourth and escape pinion arbor lower bearings. The plates are hand spotted.

Fusee: Having a wide, coarse pitch groove of about 6½ turns, giving a total period of running of some 30 hours. There is the usual stop-work and maintaining power, the wheel of brass, the stop-work with a return spring formed from a piece of wire. The maintaining detent and return spring are blued. These are also similar to Barwise No. 4307 cat. no. 91. The setting-up-work is fitted on the dial side of the front plate, the barrel arbor having an extended square at both ends. The mainspring is signed 'Gercoiton and Sons Jany 1910', the last figure could be an '8' and the name is difficult to interpret. The spring is hooked by hook and eye both to the solid, unsnailed barrel arbor and to the barrel wall. The barrel is flanged and there is no evidence of a rectangular hole for solid hooking. There are two winding clicks in the fusee.

Going train: Well made and finished, the wheels riveted to their pinions. The end of the centre pinion remote from the centre wheel is polished with the arbor.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escapement with endstones flat on both sides except the diamond set in a blued steel ring in the balance cock. The third arbor pivots run in recessed brass bushes held with screws, like those for the jewels.

Escapement: Holes remain in the back plate and balance potance foot for a Peto cross detent, its passing spring assembly and the banking for the detent. These have all been removed and replaced by a modern spring detent escapement of Earnshaw type. The brass block for the dovetailed detent is gilded and has the usual extended arm for the banking screw, and clamping and adjusting screws for the foot of the detent. Both rollers are jewelled, the discharge roller without an adjusting flat.

Balance: Later bimetallic two-armed balance, the steel parts blued, with cylindrical compensation weights each clamped by a plate and two screws, and brass timing screws in the rim at the ends of the arms. There is room for a balance of much greater diameter under the balance cock, possibly one of three arms as used by the Brockbanks. Diam. of rim 29·8 mm, h. 4·7 mm.

Balance spring: Blued steel helical spring of 12 close coils, with terminal curves, pinned to a split brass collet and a brass diamond-shaped stud. A slot has had to be cut or enlarged in the balance cock for the stud.

Going-train counts:
Great wheel (fusee) 80 teeth
Centre pinion 16 leaves, wheel 112 teeth, no crossings
Third pinion 14 leaves, wheel 90 teeth, 6 arms
Fourth pinion 12 leaves, wheel 80 teeth, 6 arms
Escape pinion 10 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 20 leaves, held by a pin through the arbor, minute pinion 24 leaves
Hour wheel 72 teeth, minute wheel 80 teeth

Provenance: Ilbert Collection, purchased from Malcolm Gardner in 1943 (reg. no. CAI-1950). Presented by Mr Gilbert Edgar C.B.E. in 1958.

Exhibited: British Clockmakers Heritage Exhibition, Science Museum, London May–September, 1952. British Watches and Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954.

Note: In the collection of the Worshipful Company of Clockmakers (cat. no. 601), there is a marine chronometer signed Brookbanks London but with no number. It still has its Peto cross detent escapement.

Bibliography: Bertele 1981, p. 163; Cecil Clutton and George Daniels, *Clocks and Watches in the Collection of the Worshipful Company of Clockmakers*, London, 1975, p. 99.

149 BROCKBANK

1800

CHRONOMETER *Plates 108e–f, 109a–b*

Signature: On the barrel bridge in characteristic script 'Brockbanks' and 'LONDON' and 'No. 4302'. On the dial 'BROCKBANKS LONDON'.

Case: 18-carat gold pair cases with the London hallmark for 1800 and maker's mark T.C. surmounted by an axe (see cat. no. 59).

Dial and hands: Engine divided. Enamel dial (see cat. no. 150) slightly curved at the edge and fixed to the dial plate by short feet and pins. Roman hour, Arabic minute numerals, signed in the upper half 'BROCKBANKS LONDON' in small capitals, subsidiary seconds to 6 o'clock.

Flat red gold hand, the minute tapered, the hour with shaped and polished heart end, the seconds missing.

Movement

Dial plate diam. 46·9 mm; front plate diam. 43·5 mm; back plate diam. 40·9 mm; frame h. 6·2 mm.

Frame: Full plate with four turned pillars, the back plate secured by pins. Detachable barrel bridge. The movement hinge screwed to the dial plate, the case catch and spring on the front plate under the dial. No dust cover.

Fusee: Keywind fusee, with stop-work, and maintaining power with a steel ratchet wheel. The setting-up-work under the dial on the front plate. The maintaining detent and its return spring of polished steel screwed to the inside of the front plate. Barrel arbor with an extended square at both ends.

Going train: The fourth wheel has 68 teeth and drives an escape pinion of 7 leaves, giving the unusual number of 17,485$\frac{5}{7}$ beats per hour.

Jewelling: Only the escapement pivots running in pierced jewels with endstones. A diamond endstone set in a blued steel ring on the balance cock.

Escapement: Peto cross detent escapement, the gilded brass escape wheel teeth have their leading edges almost on a radial from the wheel centre. Polished steel impulse roller, not jewelled, with the impulse surface leaning towards a radial from the centre. The usual jewelled discharge roller. Steel detent, the top of its foot polished, the rest left grey. Steel passing spring pinned in a square hole in a polished steel arm screwed to the underside of the top plate. A steel block, with an adjusting screw to move the passing spring towards or away from the balance staff by bending the steel arm, fixed to the balance potance foot (see fig. 9 and cat. no. 147). The leading edges of the escape wheel teeth are marked, and the detent is worn where the passing spring has rubbed.

Balance: Plain gilded brass with four arms, and four steel screws set in the rim near the end of each arm. Diam. 20·5 mm, h. 1·25 mm.

Balance spring: Blued steel spiral spring of 7 turns and without any form of thermal compensation, pinned to an oval brass collet on the balance staff and a polished steel stud on the back plate. Polished steel index on the balance cock, its tail over a graduated scale.

Balance cock: with an engraved decoration.

Going-train counts:
Great wheel (fusee) 65 teeth
Centre pinion 10 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 68 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 17,485$\frac{5}{7}$

Motion Work:
Cannon pinion 12 leaves, minute pinion 14 leaves
Hour wheel 42 teeth, minute wheel 48 teeth

The polished steel minute pinion adjusted on to a brass tube on the minute wheel.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1722).

150 BROCKBANK

c. 1800

CHRONOMETER MOVEMENT *Plates 109c–f, 110a–b*

Signature: 'No. 518 Brockbank's'. On the barrel bridge in characteristic script 'LONDON'.

Dial and hands: Flat enamel dial, cracked, fixed to the dial plate by short feet and pins. The minute and seconds markings were made with a diamond in a dividing engine on rings previously turned in the enamel. Black enamel was later applied over the markings and the dial refired. The circles scribed in the white enamel are faintly visible to the naked eye but the actual divisions under the black enamel are only discernible with a ten times or greater magnification. Roman hour numerals, Arabic minute numerals, subsidiary seconds at 6 o'clock, and signed 'BROCKBANKS LONDON' in small capitals in the upper half. The letter S fired in the back.

Flat red gold minute and hour hands, blued steel seconds hand.

Movement

Dial plate diam. 47·5 mm; front plate diam. 44·5 mm; back plate diam. 44·1 mm; frame h. 6·7 mm.[2]

Frame: Full plate with four turned pillars, the back plate secured by blued steel screws. Detachable barrel bridge. The dial plate positioned by three short turned pillars not drilled for pins, but screwed by three radial screws. No dust cover and no provision for one. Otherwise similar to cat. no. 149.

The barrel bridge, back plate and balance cock have all been altered to accommodate the balance and amplitude limiting device. A hole has been drilled in the back plate to allow access to the maintaining power spring foot screw. 72 scratched on the front plate.

Fusee: See cat. no. 149.

Going train: Normal 18,000 beats per hour train. The great wheel has the unusual number of 66 teeth.

Jewelling: The pivots of the third, fourth and escapement arbors run in jewelled bearings, the escapement with endstones.

A diamond endstone on the balance cock set in a blued steel ring. The fourth arbor jewel in the back plate a large milky ruby.

Escapement: Peto cross detent escapement, with flat brass escape wheel, not gilded, the teeth raked forwards about 24°. The impulse pallet jewelled with the impulse plane on a radial, the usual jewelled discharge roller. Steel detent, the top of its foot polished, the rest left grey, with an triangular ruby locking stone. Gold passing spring pinned in a square hole in a polished steel arm screwed to the underside of the top plate. A steel block with an adjusting screw to move the passing spring towards or away from the balance staff by bending the steel arm fixed to the balance potance foot (see fig. 9 and cat. no. 147).

Balance: Bimetallic three-armed balance with brass segment compensation weights fixed with grained steel plates and polished screws. At the end of each arm is screwed a bracket carrying a screw to limit the outward movement of each rim. Steel timing screws set near the fixed ends of each rim. Broken off screws by the end of each arm also. Rim diam. 17·4 mm, h. 1·24 mm.

Balance spring: Blued steel helical spring of $4\frac{1}{2}$ turns, with terminal curves, the upper rather short, pinned to the shaped steel collet in a square hole. The radially adjustable overhanging steel stud screwed to the back plate, and having a specially shaped block to clamp the upper terminal curve secured by a screw. Brockbanks amplitude limiting device operated by the upper coils of the balance spring. If the amplitude of the balance and spring becomes excessive the coils of the balance spring bear against a block on a pivoted arm. The arm turns against a light return spring until part of the block moves into the path of a steel stud screwed to one of the balance arms, thus preventing the balance from turning further.

Balance cock: Heavily engraved decoration all over the upper surface similar to cat. no. 147.

Going-train counts:
Great wheel (fusee) 66
Centre pinion 12 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 70 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves
Hour wheel 60 teeth, minute wheel 64 teeth

The polished steel minute pinion adjusted on to a brass tube on the minute wheel.

Provenance: Ilbert Collection; purchased from Malcolm Gardner in 1932 (reg. no. CAI-1589).

Notes:
1. No. 519 is known and has the hallmark for 1801.
2. This movement is similar to cat. no. 5.

151 NICOLAS-ROBERT ROBIN (1775–1812)
(1775–1812)
1807

WATCH WITH ROBIN ESCAPEMENT *Plate 110c–d*

Signature: On the back plate 'Robin a Paris An 1807 No. 48'.[1]

Dial and hands: Missing. No provision for a seconds hand.

Movement
Dial ring diam. 45·9 mm; front plate diam. 44·9 mm; back plate diam. 44·9 mm; frame h. 4·7 mm.

Frame: Full plate construction, four turned pillars and pins, dial ring held by four screws under the dial whose feet went through holes, and were held by pins on the inside of the front plate. No hinge or case catch. The movement retained in the case by pins and two dog screws. Detachable barrel bridge.

Separate cocks for the third and fourth arbor pivots, at both ends. A retangular hole near the edge of the front plate near the third wheel now has no function. All the brass parts gilded.

Going barrel: Given additional height by passing through a hole in the back plate. The ratchet and click under the dial on the front plate. Geneva stop-work once fitted on the cover. The mainspring hooked with an eye to the barrel and with a brace.

Going train: Pinions well made and polished, the exceptionally thin leaves having almost no addendum. The wheel teeth conventional but meshed deeper than usual. The brass wheels very thin and polished, without gilding.

Jewelling: The balance staff pivots in pierced jewels with endstones.

Escapement: Robin escapement with all the impulse transmitted from the wheel teeth to a steel pallet on the balance staff. The wheel teeth locked on steel pallets, with a large drop during impulse and a small drop on the return of the balance. The fork on the end of the pallet frame near the entry pallet intersecting a protrusion on the balance staff like a single pinion leaf. Banking for the pallet system is by a steel peg forming the projecting end of a screw set in the pallet frame and passing into a hole in the front plate. The impulse and unlocking pallets appear to be later replacements.

Balance and spring: Plain brass three-armed balance, blued steel flat spiral spring of slightly more than 10 turns with a stud and index on the balance cock. No compensation.

Going-train counts:
Great wheel (barrel) 70 teeth
Centre pinion 10 leaves, wheel 70 teeth, 4 arms
Third pinion 7 leaves, wheel 56 teeth, 4 arms
Fourth pinion 7 leaves, wheel 56 teeth, 4 arms
Escape pinion 8 leaves, wheel 16 teeth, 4 arms
Beat per hour: 17,980

Motion work:
Only the cannon pinion of conventional leaf form, with 10 leaves, remaining.

Provenance: Ilbert Collection; purchased by Ilbert from Goebel in 1932 (reg. no. CAI-1748).

Note

1. If this is the work of the celebrated Robert Robin, then he did not die in 1799 as stated by Tardy 1971, but in 1809 as stated in Baillie 1951.

152 A. L. BREGUET

c. 1813

MOVEMENT WITH DETACHED VERGE ESCAPEMENT

Plates 110e–f, 111a–f

Signature: Secret signature on the enamel dial below XII twice (as one is indistinct) ‘Breguet’ and ‘No. 971’. The number 971 is also stamped on the front plate under the dial, under the third and fourth cock. Signed at the bottom of the dial ‘BREGUET’.[1]

Case: The movement contained in a glazed brass box, the original case would probably have been similar to that of cat. no. 153.

Dial and hands: Curved enamel dial held in a recess in the front plate by a single screw above the 6. The subsidiary seconds dial recessed in the enamel of the main dial and not positioned symmetrically but at the 4. The central hole and the retaining screw hole with turned rings. The seconds’ marks were painted on and more than half are missing. The back of the dial signed ‘Borel 63’.

Blued steel hands, moon type.

Movement

Front plate diam. 58·8 mm; front plate th. 4·1 mm; overall frame h. 12·0 mm.

Frame: Open Lepine construction built up on the recessed front plate. The brass parts gilded, the steel screws blued. The movement was retained in its case by two dog screws and a peg at the pendant. The escapement mounted on a separate sub frame.

Going train: Lodged between cocks on both sides of the front plate. The wheels not gilded. Breguet stop-work on the going train barrel allowing for turns of wind.

Jewelling: The pivots of the centre, third and fourth arbors of the going train in pierced jewels, those of the escapement similar and with endstones. The steel endstone plates for the pivots of the pallet and fork arbor not jewelled. Resilient jewelling for the balance staff pivots.

Escapement: A verge escapement made detached by the addition of an extra escape wheel working with a pair of pallets for locking, and a fork and roller for unlocking.

On the balance staff are two rollers with inset pieces of jewel to receive impulse at each alternate swing of the balance from a five-toothed escape wheel. Behind this escape wheel, on the arbor of the escape pinion, is mounted a small five-toothed wheel. This wheel is alternatively locked on one or other of a pair of pallets whose frame is mounted on the same arbor as a fork with dart. On the balance staff, below the lower impulse roller, is mounted another double roller with what appears to be an impulse pin on the larger and a passing hollow on the lower roller. This fork and roller system is similar to that to be found in any modern club-toothed lever escapement. However, in this instance no impulse is transmitted through the fork and roller, they merely provide the means for locking and unlocking the smaller escape wheel via the pallet system, and providing safety action to prevent unlocking of the escapement during the supplementary arc of the balance.

Balance: Bimetallic three-armed balance silver-brass and steel with gold timing and compensation screws, and brass screws for poising. Only one screw at the end of each rim and a series of 9 dots whose purpose is obscure. Diam. 21·2 mm, h. 2·2 mm.

Balance spring: Blued steel spiral spring with Breguet overcoil and terminal curve, free sprung to a most unusual design of stud under a steel plate held with two screws, on the centre line of the balance cock. The part of the stud beneath the steel plate is spherical and sits in a V-groove in the cock. The stud can thus align itself in all planes except that which affects the height of the spring. Such an arrangement is very rare.

Repeating work: Typical Breguet quarter repeating with a single hammer working ‘dumb’, and with jump hour mechanism (see cat. no. 153). The repeating mainspring visible through a hole in the cock that supports its arbor, there being no cover on the barrel. The speed of striking of the repeating train is controlled by a recoil escapement which has the travel of its pallets limited by an adjustable flexible stop.

Going train counts:
Great wheel (barrel) 90 teeth
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 50 teeth, 4 arms (contrate)
Escape pinion 8 leaves, 2 wheels, 5 teeth each
Beats per hour: 18,000

Motion work:
Hour and minute wheels 14 teeth

Repeating work:
First wheel 60 teeth
Second wheel 46 teeth
Third wheel 36 teeth
Escape wheel 16 teeth
Three pinions of 8 leaves each.

Provenance: Purchased: 1961 (reg. no. 1961, 7-2,1).

Note:

1. According to the records of the Maison Breguet in Paris, this watch was sold twice to M. Mainet, as No. 971 in 1813 and as No. 1802 in 1818. Later it was sold as No. 3366 to M. Fatton for J. Whelley in 1825 for 3,600 francs. The escapement was made by Le Roy.

Bibliography: E. Bornschein, ‘Ein original Breguet-Uhrwerk’, *Schriften der Freunde alte Uhren, III*, pp. 65, 66; Daniels 1975, pp. 314–317.

153 BREGUET ET FILS

Before 1835[1]

WATCH WITH ROBIN ESCAPEMENT *Plate 112a–d*

Signature: On the enamel dial BREGUET ET FILS and secret signature 'Breguet' and 'No 36'.

Case: Open face, with gold bezel and back, and gold on silver middle, all engine-turned on the outside. Glazed cuvette, with a hole for the key for winding. Pendant with push-piece to operate the repeating work. Back snapped into a bezel.

Inside back 805 and 36 over B and a bull in a cartouche with a 3 above the bull, also the letters LJ with a falcon on a perch in a cartouche. On the front of the pendant a P surmounting a bull's head with a dot either side of the head. These marks are the Paris marks for 1822–38. There is also a case maker's mark. Diam. 65·0 mm, h. 19·0 mm.

Dial and hands: The certificate states that the dial is silver; however, this may be a mistake on what is a copy of the original certificate made from records kept by the firm.

Flat enamel dial with signature and secret signature held by a single screw between the subsidiary calendar and seconds dials in a recess in the front plate.

Blued steel hands.

Movement

Ebauche marks 1802 (stamped on) front plate

Front plate diam. 58·8 mm; front plate h. 3·65 mm.

Frame: Open Lepine construction built up on the recessed front plate. The brass parts gilded, the steel screws with polished heads. The movement retained in the case by three dog screws and a peg near the pendant.

Going train and barrel: Lodged between cocks on both sides of the front plate. The wheels not gilded. Breguet stop-work on the going barrel allowing three turns of wind. A slot in the barrel allowing the disposition of the spring to be seen.

Jewelling: The rear pivot of the centre arbor and the pivots of the rest of the going train and escapement in pierced jewels. The escapement with endstones in steel endpieces. The pallets and two impulse pins also jewelled. Resilient jewel settings for the conical pivots of the balance staff.

Escapement: A form of Robin escapement. The broad teeth of the brass escape wheel leaning backwards and slotted to retain oil, the slots in various positions to spread the oil retention across the face of the pallet stones. The teeth locked alternately by one of the two pallets. At each clockwise swing of the balance, as seen looking at the escapement from the back, impulse is given through the exit pallet as in a lever escapement. When the balance returns in the anticlockwise direction, impulse is given by an escape wheel tooth directly to a small pallet on the edge of the large roller on the balance staff. Only the exit pallet has draw and its impulse face is concave. There is resilient mounting between the fork and the pallet frame, and banking is achieved between the hole in the fork and a tube adjusted onto the escape wheel arbor. Two banking screws were also provided at the end of the tail of the fork, one is now missing, but these and the thick rimmed three-armed wheel on the pallet arbor appear to have no function.

Balance: Bimetallic two-armed balance, the gold compensation and timing screws faired inside the edge of the rim to reduce air resistance to motion. The four integral bimetallic rims appear to be made of steel and silver brass. Diam. 22·6 mm, h. 1·5 mm.

A balance stop acting on the rims is operated by a short lever projecting from the edge of the movement. It can be operated when the back is opened. The stop is designed to hold the balance away from the dead point so that the watch will self start.

Balance spring: Blued steel free-sprung spiral spring with an overcoil and terminal curve pinned to a stud retained by a plate and two screws on the centre line of the balance cock. A 'rectangular' steel collet.

Repeating work: Breguet half/quarter repeating with a single hammer on a wire gong. (This type of repeating work with jump hour hand is described fully in F. LeCoultre *Les Montres Compliquées*, Bienne, 1952, pp. 128–37). The speed of the repeating train is controlled by a recoil escapement which has the travel of its pallets limited by an adjustable flexible stop.

Going-train counts:
Going barrel 90 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 80 teeth, 4 arms
Escape pinion 8 leaves, wheel 15 teeth, 4 arms

Motion work: The minute wheel carried on the hour snail and star wheel is jumped forward $\frac{1}{12}$ of a turn at each hour by a peg on the cannon pinion. Minute and hour wheels 24 teeth.

The simple calendar wheel carrying the hand showing only the date has 62 teeth and is advanced by a tooth space every 12 hours by a finger piece on the minute wheel operating a pivoted lever.

Provenance: Ilbert Collection; purchased by Ilbert from Webster in 1932 (reg. no. CAI-1189).

Note:

1. Supplied 1 July 1835, and sold to a Professor Schumacher for 3,600 francs, probably having been in stock for some years. Certificate No. 2383, 5 March 1896.

154 THOMAS PRITCHARD

c. 1856

CHRONOMETER MOVEMENT *Plates 112e–f, 113a–b*

Signature: On back plate 'Tho^{s} Pritchard Liverpool N° 1859'. On the dial 'PRITCHARD'S PATENT CHRONOMETER LIVERPOOL' in the upper half.

Dials and hands: Flat enamel dial with subsidiary seconds having the centre sunk, secured to the front plate of the movement by three feet and pins.

White gold fleur-de-lis minute and hour hands, hour hand has a piece broken off, blued steel seconds hand.

Movement

Ebauche marks 18, 0.

Front plate diam. 45·8 mm; back plate diam. 41·8 mm; frame h. 7·0 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate retained by recessed blued steel screws. There was once a movement hinge attached to the dial side of the front plate, now missing, but no provision for a case catch. The movement retained in its case by two dog screws and two pegs set in the edge of the front plate.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. The setting-up-work in a shallow recess on the front plate under the dial, the barrel arbor with an extended square on that end only.

Going train: The centre arbor drilled for the hand-set arbor which is integral with the cannon pinion and pinned to the hand-set square. The escape wheel is placed below its pinion instead of above and the fourth wheel higher than usual. The brass wheels burnished and not gilded, the steel pinions and arbors well finished and polished. The central bosses of the centre and third wheels and the underside of the great wheel with a frosted finish.

Jewelling: The pivots of the fourth arbor and those of the escapement in pierced jewels, only those of the balance with endstones. A diamond endstone set in a blued steel ring in the balance cock. The escape and pallet arbor jewels with curved faces against the pivot shoulders.

Escapement: A form of pivoted detent escapement, patented on 8 January 1856, No. 62, by H. Stuart and T. Pritchard. The brass escape wheel resembles that for an English ratchet-tooth lever escapement. On the arbor of the pivoted detent is a jewelled steel locking pallet, and above this a polished steel detent carrying the steel passing spring. The free end of the passing spring is banked against a pin at the balance end of the detent. There is no return spring for the detent but its tail is banked against a pin when the escape wheel is locked.

Immediately below the collet supporting the balance on its staff is a steel roller carrying a triangular-shaped ruby pin pointing downwards. The passing spring is in the path of this pin and is contacted by it for unlocking and passing action. Another pin stands upwards from a short continuation of the detent at the side of the balance staff. This provides safety action against the polished edge of the roller. A cresent-shaped notch in the roller allows the pin to move towards the detent during unlocking, and then returns the detent by the end of the notch striking the pin. A triangular-shaped steel pallet on the balance staff below the jewelled roller receives impulse from the escape wheel teeth. There is apparently either no draw at all, or else only a very slight amount between the escape wheel teeth and the detent locking pallet.[1]

Balance: Bimetallic two-armed balance with gold screws, unusually small in proportion to the rest of the movement. Diam. 17·5 mm, h. 1·1 mm.

Balance spring: Blued steel flat spiral spring of 8½ turns. A polished steel stud on the back plate, and index on the balance cock. The brass collet is round and split.

Going-train counts:
Great wheel (fusee) 74 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1939 (reg. no. CAI-1746).

Note:

1. The small size of the balance and the strength of the mainspring suggest that the escapement has a low mechanical efficiency.

155 R. THOMPSON

c. 1860[1]

WATCH MOVEMENT WITH ROBIN-TYPE ESCAPEMENT *Plates 113c–f, 114a–b*

Signature: On the back plate 'R. Thompson, NEWCASTLE on Tyne London Patent Chronometer 2082'.

Dial and hands: Flat enamel dial with separate sunk central portion, signed 'Chronometer 2082' in the upper half, see Drake cat. no. 159 for a very similar dial and hands. The dial attached directly to the front plate by three feet and pins, and marked on the reverse B.

Gold minute and hour hands, blued steel sweep centre seconds hand.

Movement

Ebauche marks 18, 2, H.F., 2082 (see cat. no. 159). Also under the balance cock 2082 HF. Front plate diam. 46·2 mm; back plate diam. 43·2 mm; frame h. 7·9 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate retained by recessed blued steel screws. The construction similar to cat. no. 159 but laid out for a non-reversed fusee and the fourth arbor planted at the centre. The movement fixed in its case by a hinge at 12 o'clock, and a peg opposite fixed in the edge of the front plate. All the brass parts gilded.

Fusee: Keywind fusee, with the usual stop-work and maintaining power with a steel maintaining ratchet wheel. The setting-up-work fitted in a shallow recess on the dial side of the front plate, the barrel arbor with an extended square on that end only.

Going-train: The offset centre arbor hollow, for the squared hand-set arbor carrying a wheel meshing with the minute wheel to drive the motion work. The fourth arbor planted at the centre and carrying the sweep centre seconds hand on the lower extended pivot.

Jewelling: The lower pivot of the centre arbor and those of the fourth escape wheel and balance arbors in pierced jewels.

Those of the escape wheel and balance with endstones. The pivots of the pallet frame are not in pierced jewels. The jewels for the fourth arbor pivots are *bombé*.

Escapement: A type of Robin escapement in which the teeth of the escape wheel are locked alternately on jewelled pallets in a steel pallet frame. The drops are alternately large and small, and during the large drop an escape tooth transmits impulse to a jewelled impulse roller on the balance staff. A steel lever on the underside of the pallet frame works in conjunction with a steel pin protruding from below the impulse roller to unlock the escapement. Fork and roller safety action is provided by the shaped edge of the notch and the balance staff itself, and with a slot filed behind the steel pin on the impulse roller, as in a modern pin-pallet lever escapement. The pallets have draw, so that when the escape wheel is locked the lever is held clear of the roller and banked on one or other banking pin. The brass escape wheel, burnished on both sides, not sunk out for lightness. The steel roller, pallet frame and fork polished.

Balance: Bimetallic two-armed balance with gold screws. Diam. 16·4 mm, h. 1·2 mm.

Balance spring: Blued steel spiral spring of $11\frac{3}{4}$ turns without an overcoil or terminal curve, pinned to a polished steel stud on the balance cock, and round brass collet. A polished steel index fitted on the balance cock.

Going train counts:
Great wheel (fusee) 72 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 56 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon wheel 36 teeth, minute pinion 6 leaves
Hour wheel 72 teeth, minute wheel 36 teeth
Transmission wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1932 (reg. no. CAI-1832).

Note:

1. Although this chronometer does not have a Patent Union Chronometer escapement, it is assumed to fit into the same series and therefore to predate those with higher serial numbers.

156 MAKER UNKNOWN

c. 1860

WATCH MOVEMENT WITH ROBIN TYPE ESCAPEMENT *Plate 114c–f*

Signature: On the back plate 'Union Patent 2291'.

Dial and hands: Flat enamel dial, slightly damaged, with sunk subsidiary seconds, and signed in the upper half 'Union Patent 2291', attached to the front plate by three feet and pins. The back of the dial marked B and 91 (see cat. nos 155, 157 and 159).

Gold minute and hour hand, blued steel seconds hand.

Movement

Ebauche marks: H.F., 16 2 2291 (see cat. nos 155, 157 and 159). Both on the underside of the balance cock foot and on the plate under the foot a C embracing an O; most of the frame parts are marked 91.

Front plate diam. 44·4 mm; back plate diam. 42·0 mm; frame h. 7·2 mm.

This movement, apart from being slightly smaller, resembles that of a Patent Union Chronometer, the most obvious point of similarity being the shape of the fourth and escape wheel bridge. There are, however, the following detailed differences:

The fourth wheel is fixed to the other end of its pinion and so is above the third and centre wheels, and there is no sink for it in the front plate. The centre wheel is not crossed out, and the pinion is solid and not drilled for the hand-set arbor.

There is a movement hinge, and a case catch and spring on the dial side of the front plate, and the train and escapement bridge is divided in two and finished to a different shape.

The train pivot not jewelled, only the pivots of the escapement in pierced jewels. The endstone in the balance cock of ruby.

Fusee with five turns, normal maintaining power, steel maintaining ratchet wheel.

Escapement: The brass escape wheel has only a single set of teeth, for both locking and impulse. This is an inferior arrangement to that of the Patent Union Chronometer because oil applied to the pallets will inevitably find its way onto the impulse jewel and spoil the rate. The patent of 1863 corrected this fault.[1] The pointed lever arm top pivot runs in an adjustable cock, as in cat. nos 157, 158 and 159. The ruby roller on the balance staff is made of brass and could be a later replacement. The escape wheel is not sunk out for lightness.

Balance: Bimetallic two-armed balance with brass compensation and quarter screws. Diam. 16·1 mm, h. 1·1 mm.

Balance spring: Blued steel flat spiral spring of $14\frac{3}{4}$ turns with an overcoil and terminal curve, pinned to a polished steel stud on the balance cock and a round brass collet.

Going-train counts:
Great wheel (fusee) 72 teeth
Centre pinion 10 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 63 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 16,200

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1930 (reg. no. CAI-1829).

Note

1. A search of the patent records has not revealed a patent corresponding exactly with this escapement. It is therefore assumed that it is an improvement on the original patent no. 233 of 1859 and preceded that protected by No. 2184 of 1863.

157 ARNOLD AND LEWIS

c. 1865

MOVEMENT WITH ROBIN TYPE ESCAPEMENT
Plate 115a–d

Signature: On the back plate 'Arnold and Lewis late Simmons 7 St. Anns Square Manchester. Patent Union Chronometer 3001'.

Dial and hands: Flat enamel dial pinned directly to the front plate, the centre recessed. Roman hour numerals and an inscription in the upper half *Chronometer 3001 Arnold and Lewis Late Simmons Manchester*. On the reverse the marks 01 and B (see cat. nos 159, 155 and 156).

Gold minute and hour hands, steel sweep centre seconds hand.

Movement
Ebauche marks 16 2 H.F. and 3001 on the front plate under the dial, C embracing an O, 01 under the balance cock and C embracing an O under the cock on the plate (see cat. nos 156 and 159). Front plate diam. 44·8 mm; back plate diam. 42·1 mm; frame h. 8·2 mm.

Frame: Three-quarter plate with three turned pillars, the back plate secured by blued steel screws. No dial plate but a thick front plate recessed on the dial side, and with sinks turned on the other side to accommodate the going train wheels. The movement was secured in its case by a brass peg and a dog screw on the back plate.

Fusee: Keywind reversed fusee fitted with stop-work and maintaining power, the setting-up-work under the dial on the front plate. The maintaining ratchet wheel steel.

Going train: The brass wheels not gilded but finished by polishing or burnishing flat. The centre wheel offset, and hollow for the hand-set arbor carrying the steel wheel connecting with the motion work at the centre. The fourth wheel planted at the centre.

Jewelling: All the bearings of the going train jewelled as far as the centre wheel: escapement bearings with endstones, a ruby in the balance cock. A slotted ruby passing roller fitted on the balance staff. The pallets jewelled.

Escapement: Patent Union Chronometer. The escape wheel, with teeth in two planes like a duplex escape wheel, is mounted on its pinion so that the short resting teeth standing radially from the rim are in the same plane as a pair of pallets. These pallets are pivoted between the front plate and an adjustable cock to rock them towards or away from the escape wheel as in cat. nos 156, 158 and 159). Below the pallet frame and fixed to it is a pointed steel arm working between banking pins and intersecting the slotted ruby roller on the balance staff.

When trying to turn, the escape wheel is held by one of the pallets, whose faces are inclined to have negative draw so that the pallet frame in turn tries to rotate. It is prevented from doing so, and hence the escape wheel from turning, by the arm touching the ruby roller on the balance staff. When the balance returns clockwise, seen from the back, the passing roller allows the steel arm to pass from one side to the other. A resting escape tooth leaves one pallet and at once falls onto the other, the wheel hardly advancing. The steel arm at once returns against the balance staff where it is held while the balance continues clockwise and starts to return anti-clockwise. At an appropriate moment near the rest position of the balance and spring, the steel arm is again allowed to pass. As soon as the escape wheel is released one of the short teeth standing vertically on its rim contacts the jewelled pallet on the impulse roller and impulse is given. The escape wheel is then locked again on the first pallet.

Impulse is given at each anticlockwise swing of the balance. With a 14,400 train the sweep centre seconds hand advances by a half second jump.

This escapement is something of a composite of the duplex, the lever and the chronometer. Although it is not a detached escapement, since the steel arm is in rubbing contact with the passing roller, the pressure with which the arm rubs is less than in the duplex owing to the mechanical demultiplication.[1]

Balance: Bimetallic, gold quarter and compensation screws. Diam. 18·0 mm, h. 1·7 mm.

Balance spring: Blued steel helical spring, 7 complete turns with terminal curves at each end. The upper terminal curve pinned directly to a stud on the balance cock.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 56 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 36 teeth free on a hollow steel centre post, minute wheel 36 teeth
Driving wheel 36 teeth, friction tight on the end of the hand-set arbor running through the hollow offset centre pinion arbor
Hour wheel 72 teeth, minute pinion 6 leaves

Provenance: Ilbert Collection; purchased from Messrs Arnold and Lewis in 1931 (reg. no. CAI-1830).

Note

1. The first patent, No. 2432, with dealing with an early form of this escapement was taken out by G. Morton in 1856. An improvement, Patent No. 233, was patented in 1859 by C. G. Kelvey and W. Holland. The patent for the final form of the Patent Union Chronometer escapement, No. 2184, was taken out in 1863, also by Kelvey and Holland.

158 MAKER UNKNOWN, but English

c. 1865

WATCH MOVEMENT WITH ROBIN TYPE ESCAPEMENT *Plates 115e–f, 116a–b*

Signature: On the back plate 'Patent Union Chronometer 3060'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, secured to the front plate by three feet and pins. Some damage to enamel. On the back the marks 25 and B in the enamel.

Gold minute and hour hands, blued steel seconds hand.

Movement
Ebauche marks H.F., 18, 2, 3060; also O under the balance cock foot on both plate and foot.

Front plate diam. 46·4 mm; back plate diam. 43·0 mm; frame h. 7·7 mm.

Frame: Half plate construction with three turned pillars, the back plate secured by recessed, blued steel screws. The movement held in its case by a peg in the edge of the front plate and a dog screw on the edge of the back plate. An unusual fourth, escape wheel bridge with the end turned back on itself. The top pivot of the pallets in an adjustable cock as in cat. nos 156, 157 and 159. The brass parts gilded.

Fusee: Keywind fusee with the usual stop-work and maintaining power, the maintaining ratchet wheel steel. Setting-up-work in a shallow recess in the front plate, the barrel arbor with an extended square on that end only.

Going train: The centre arbor hollow for the hand-set arbor carrying the cannon pinion. Conventional train and layout, the brass wheels burnished on both sides and not gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the fourth and escapement arbors in pierced jewels, those of the escape wheel and balance staff pivots with endstones.

Escapement: Patent Union Chronometer escapement (see cat. no. 157).

Balance: Bimetallic two-armed balance with gold screws and quarter screws. Diam. 18·6 mm, h. 1·4 mm.

Balance spring: Blued steel spiral balance spring with an overcoil and terminal curve. A polished steel stud on the balance cock and a round brass collet on the balance staff. Regulation by a polished steel index on the balance cock.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 63 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 16,200

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves.
Hour wheel 40 teeth, minute wheel 36 teeth.

Provenance: Ilbert Collection; Ilbert purchased this watch in the Caledonian Market in 1932 (reg. no. CAI-1742).

159 E. DRAKE

c. 1865

MOVEMENT WITH ROBIN-TYPE ESCAPEMENT

Plate 116c–e

Signature: On back plate 'E. Drake Halifax Patent Union Chronometer 3199'.

Dial and hands: Enamel dial with Roman hour numerals and recessed centre, secured by three feet and pins to the front plate. Signed in the upper half 'Chronometer 3199', on the back in the enamel B. (see cat. nos 155, 156 and 157).

Gold minute and hour hands, blued steel sweep centre second hand.

Movement
Ebauche marks 18 H.F. 3199, and 99 under the balance cock with C embracing an O on the plate under the cock (see cat. nos 157, 159, 156).

Front plate diam. 46·4 mm; front plate th. 3·73 mm; frame h. 8·0 mm; back plate diam. 43·3 mm.

Frame: Similar to cat. no. 157, but the fusee and barrel positions reversed and the train laid out on the opposite side of the centre. The balance cock and escapement also turned round the opposite way. The movement secured in its case without a hinge or catch, but with a single positioning peg and one case screw.

Fusee: Reversed as in cat. no. 157, an unusual stop-piece screwed to the back plate.

Going train: Similar to cat. no. 157.

Jewelling: Similar to cat. no. 157.

Escapement: Similar to cat. no. 157 Patent Union Chronometer.

Balance: Bimetallic two-armed balance with gold screws, and quarter nuts on steel screws set on the inside of the rim. Diam. 18·7 mm, h. 1·8 mm.

Balance spring: Blued steel helical spring of 8 complete turns, with a terminal curve, free sprung to a polished steel stud on the balance cock and a brass collet on the balance staff.

Going-train counts:
Great wheel (fusee) 75 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 56 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 30 teeth, minute wheel 30 teeth, offset driving wheel 30 teeth
Hour wheel 72 teeth, minute pinion 6 leaves

Provenance: Ilbert Collection; purchased by Ilbert from Benson 1935 (reg. no. CAI-1828).

160 C. HANSON, English

c. 1860

CHRONOMETER MOVEMENT *Plate 117a–d*

Signature: On the back plate 'C. Hanson's No. 28 Patent Chronometer'.

Dial and hands: None.

Movement

Ebauche marks J.W. 16, 2̊, 28.

Front plate diam. 43·9 mm; back plate diam. 40·0 mm; frame h. 6·3 mm

Frame: Full plate construction, the back plate retained by screws, turned pillars, detachable barrel bridge. The movement hinge and case catch lodged on the recessed front plate under the dial. No dial plate, the dial feet passing through holes in the front plate and retained by pins. The back plate recessed for the balance, fitting flush with the plate, and having an engraved shaped balance cock. A separate bridge for the upper escapement bearings screwed to the under side of the back plate. All the brass parts gilded.

Fusee: Keywind fusee of the usual construction, with maintaining power having a steel ratchet wheel.

Going train: Usual construction and layout.

Jewelling: The balance staff and lower escape arbor pivots in pierced jewels with endstones. The upper escape arbor pivot in a pierced jewel. No other jewelling.

Escapement: A type of pivoted detent without the usual passing spring. The escape wheel teeth are locked on a hollow crescent resembling the cylinder of a cylinder escapement. On the impulse swing of the balance, a steel pin below the impulse roller contacts the nose of the detent. This turns the crescent, releasing a tooth of the escape wheel to give impulse. A light spring acting on a flat on the detent arbor returns the detent ready to lock the escape wheel. On the return of the balance the detent is moved so that the escape tooth is locked deeper on the edge of the crescent.[1]

Balance: Plain steel three-armed balance, flat spiral balance spring of 10 full turns, with an index on the balance cock. No compensation. Diam. 16·0 mm, h. 0·76 mm.

Going-train counts:
Great wheel (fusee) 75 teeth
Centre pinion 10 leaves, wheel 64 teeth, 5 arms
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 18,000

Motion work:
Canon pinion 12 leaves remainder missing.

Provenance: Ilbert Collection; purchased by Ilbert in the Caledonian Market in 1932 (reg. no. CAI-1604).

Note

1. The patent, No. 1950, was granted on 27 August, 1859. Although this watch cannot have been intended for precision work, the variant of the pivoted detent escapement is ingenious and easier to make than a normal pivoted detent. It is also lighter and more robust.

161 CHARLES FASOLDT (1818–1898)

c. 1870

WATCH WITH FASOLDT'S ESCAPEMENT
Plates 117e–f, 118a–d, 119a–b

Signature: C. FASOLDT ALBANY, N.Y. NO 384 PAT. FEB. 1.1859 APR. 5. 1864 and MARCH 7 1865.

Case: Heavy silver hunter case, with gold joints, the front cover and back engine-turned, the front centred with an engraved shield and foliage, the back centred with two small turned rings. The winding stem retained by a screw in the pendant pipe. The inner dome with a band of fine engine-turning around the edge. The case numbered 344 on the front, middle and back, with the mark E.H. and a lion in separate cartouches in the front and back. The lock spring steel, the replacement fly spring brass. All pieces including the pendant and bow also marked with a swan. Diam. 57·0 mm, h. over the glass 16·6 mm.

Dial and hands: Flat enamel dial without signature, Arabic hour numerals, subsidiary seconds at 6 o'clock, retained by two feet and flat screws in the front plate.

Steel spade hour, plain minute and seconds hands.

Movement

Front plate diam. 46·6 mm; frame h. 9·1 mm over winding bridges, 8·2 mm over train bridges.

Frame: Open bar movement made of nickel brass, retained in its case by two dog screws and a positioning peg. The bridges and cocks retained by steel screws with polished heads. The massive front plate recessed for the motion work.

Going barrel: Also made of nickel brass, fitted with a four-turn Geneva stop-work. The upper surface finished with a sunburst decoration.

Keyless winding: By massive steel wheels, the barrel ratchet wheel only having Wolf tooth form, working with a double-ended click which can be turned round when one end is worn. The long screws pass through clearance holes in the winding bridges and covers, and into threaded holes in the front plate. Hand setting by a separate key applied to the square on the end of the arbor passing through the hollow centre pinion with the cannon pinion adjusted on the other end.

Going train: The brass wheels gilded, and with the crossed out portion sunk below the level of the rims. Square-bottomed wheel tooth forms. The steel pinions with round-bottomed tooth forms.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, those of the escape pinion and balance staff with endstones. Gold jewel settings for the third and escape upper and a gold ring around the centre arbor square. The jewels of a red colour.

Escapement: Fasoldt escapement with two gilded brass escape wheels. The larger wheel is locked and released alternately by one or other of the two lower pallets. The large upper pallet receives and transmits impulse in one direction only to the balance via an impulse pin set on a large radius from the balance centre. Banking pins are set in the front plate and safety action provided by a hollowed roller on the balance staff and short horns on the fork, working on the same principle as the Massey roller. (See Clutton and Daniels, *Watches* pp. 42, 133 and 134, see also Chamberlain, '*It's About Time*', pp. 92–4 and 135–6.)

Balance: Gilded bimetallic balance. The impulse 'roller' a bar carrying a round impulse pin, the small roller recessed to lighten it. Diam. 20·6 mm, h. 1·6 mm.

Balance spring: Exceptionally large diameter relative to the balance. Spiral steel spring of just over nineteen turns with an overcoil formed to suit the index but without a terminal curve.

Index: This is gold and mounted on the balance cock. Fine adjustment is made by turning the long screw set in the free end of the index beyond the pins. The pins move in an arc of a circle of very large radius. Both the curb pins and the stud will move, the stud less than the pins, thus regulating the watch will also put it out of beat.

Going-train counts:
Great wheel (going barrel) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheel 15 teeth each, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 30 teeth, both brass and crossed out

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1199).

Bibliography: See Joachim Mauss, 'Charles Fasoldt Individualist im Meer der Massenproduction', *Alte Uhren*, October 1984, pp. 16–20.

162 CHARLES FASOLDT

1870

WATCH MOVEMENT WITH FASOLDT'S ESCAPEMENT
Plates 119c–d, 120a–b

Signature: 'C. FASOLDT ALBANY NY PAT Feb 1 1859 April 5 1864 March 7 1865'.

Dial and hands: Enamel dial with signature 'C. FASOLDT'S PATENT CHRONOMETER, ALBANY, N.Y.', with sunk subsidiary seconds, retained by two feet and dog screws.

The steel lyre hands probably of Swiss origin, judging by the design and colour. Seconds hand of the same colour.

Movement
Ebauche marks (punch) 174 and 74 on various parts; also 338.

Front plate diam. 45·0 mm; front plate th. 3·0 mm (reduced to 1·5 mm); frame h. 8·2 mm.

Frame: Open bar movement, of gilded brass, retained in its case by a single dog screw and two pegs. The frame numbered under the balance cock and on the pallet bridge 'No. 338' and under the dial on the front plate and bridges 174 and 74.

Going barrel: Keywind going barrel gilded, with four-turn Geneva stop-work on the cover. The mainspring h. 2·90 mm, th. 0·24 mm. The ratchet wheel made of brass, with pivoted steel click and gilded steel return spring.

Going train: Unusually thick brass wheels, especially the fourth, 0·60 mm thick, the centre and third with crossed out portions sunk. All the wheels gilded.

Jewelling: The pivots of the third, fourth and escapement arbors in clear sapphire jewel holes. Only the balance jewels with endstones. The train jewels flat on the underside, very domed on the upper side with small oil reservoirs.

Escapement: Similar to cat. no. 161.

Balance: Bimetallic two-armed balance with platinum screws, the steel parts blued. Diam. 19·3 mm, h. 1·6 mm.

Balance spring: Similar to cat. no. 161, 18 turns of spring.

Index: Similar to cat. no. 161, but not of gold and much longer, lying along the length of the cock.

Going-train counts:
Great wheel (going barrel) 80 teeth
Centre pinion 10 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 6 arms
Fourth pinion 10 leaves, wheel 80 teeth, 6 arms
Escape pinion 8 leaves, wheels 15 teeth each, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth, both crossed out

Provenance: Ilbert Collection; purchased by Ilbert from Jauncey in 1931 (reg. no. CAI-1204).

163 MAKER UNKNOWN

c. 1900

CHRONOMETER MOVEMENT *Plate 120c–e*

Signature: On the barrel bridge 'J. W. Jennings BIRMINGHAM 14756'.[1]

Dial and hands: None.

Movement
Ebauche marks 12, 4. and on the underside of the balance cock W.C.

Front plate diam. 38·3 mm; back plate diam. 36·0 mm; frame h. 7·6 mm.

Frame: Typical English full plate construction. The brass parts electro-gilded.

Fusee: The usual construction, steel maintaining ratchet wheel.

Going train: The usual construction, the brass wheels burnished but not gilded.

Jewelling: Only the balance staff pivots in pierced jewels with endstones.

Escapement: Originally an English ratchet tooth lever escapement, later replaced by a form of detent escapement. The balance staff carries a table roller without a notch, and a steel pallet as in a duplex escapement. Impulse is given to the steel pallet by a ratchet-tooth lever escape wheel. Locking of the escape teeth occurs on a steel locking piece carried on the end of a spring detent. This detent is carried on a brass mounting with adjustments for depth of locking and spring tension. A pivoted detent performs the functions of unlocking the spring detent, and of passing action, when displaced by a jewel pin on the table roller. The pivoted detent carries another jewel pin to unlock the spring detent, and has a fine leaf spring to return it to rest against the stronger spring detent. It also has a forked tail so that it can be moved aside to remove or replace the balance.

Balance and spring: Plain steel three-armed balance, undersprung with a blued steel flat spiral spring of 10 full turns. Originally there was an index, now only the scale remains on the back plate. No compensation. Balance diam. 18·0 mm, h. 0·8 mm.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 10 leaves, wheel 64 teeth, no crossings
Third pinion 8 leaves, wheel 60 teeth, 5 arms
Fourth pinion 8 leaves, wheel 56 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work: Missing.

Provenance: Ilbert Collection; purchased by Ilbert in 1937 (reg. no. CAI-1831).

Note

1. This is an experimental piece by an unknown maker.

164 MAKER UNKNOWN

Possibly the early 1920s

AIRCRAFT CHRONOMETER (?) *Plates 120f, 121a–b*

Box: The movement contained in a turned aluminium canister, in two halves, the lower half pushing into the upper half. The bottom is adjusted tight in a recess, it has a central brass bush held with three screws for the original winding arbor, now missing, and three equally spaced holes in the bottom for the fixing screws. There are two small holes in the side and a positioning peg for the middle plate of the frame which fits up against a narrow turned shoulder. There is a removable glazed top fitting on the upper half of the canister. Overall diam. 82·3 mm, h. 60·0 mm.

Dial and hands: All missing. The dial was fixed with three feet and pins, probably without a dial plate. The indications for the hours and minutes and for the seconds were offset. There was also a reserve of going indicator.

Movement

Most of the frame parts are punched 5.

Plate under the dial diam. 71·6 mm; middle plate diam. 78·4 mm; lowest plate diam. 75·1 mm; overall frame h. 32·7 mm; lower frame h. 18·9 mm; upper frame h. 16·3 mm.

Frame: Composed of three plates, in two tiers, each tier separated by three turned pillars, with retaining nuts and washers. The plates, bridges and cocks are made of aluminium, the pillars of steel. In the lower part of the frame, towards the bottom of the canister, are planted the fusee, barrel and their associated parts. In the section above are planted the going train and the escapement. The balance staff bearings are in the middle plate and in a cock on the back plate. There is a detachable barrel bridge with two retaining screws and two positioning pins. The mechanism is apparently intended to run dial up or approximately that position, as steel end plates are provided for all the going-train pivots on their lower ends.

Fusee: Both the fusee cone and barrel are made of aluminium, English stop-work and Harrison's maintaining power are fitted. The maintaining ratchet wheel and great wheel are made of brass, the maintaining detent and spring are combined in a single steel piece. The fusee arbor is squared at the back, and carries a turned steel boss held with a pin through the arbor. A large brass wheel fits free to turn on a shoulder on the boss and is held on by a steel ratchet wheel with two screws going into the boss. Steel clicks and brass springs are fitted on the brass wheel. A pinion was once planted in the centre of the back plate with an arbor for winding passing through a brass bush in the bottom of the canister. This pinion must have been in permanent engagement with the winding wheel. Such an arrangement causes small variations in the torque output of the fusee.

The mainspring barrel has a snap-on cover on both ends, a brass bearing bush is fitted into each cover. The steel barrel arbor has a large brass snailed boss. The very well finished and blued mainspring is signed 'Leborne et Cie 1869', it is attached by a hook and eye at both ends. Setting-up-work is fitted on the detachable barrel bridge.

Going train: Conventional but well made train with brass wheels having a grained finish and square-bottom tooth form. The pinion leaves, the ends of the pinions and the arbors and pivots are well finished and polished. The pinion leaves are well cut with square bottoms. The centre arbor is planted between the back and front plates, the rest of train between the middle and front plates. The lower third and fourth pivots run in separate cocks on the underside of the middle plate, the fourth upper pivot in a cock on the side of the balance cock. Brass bushes are provided for all the pivots with steel endpieces for the lower bearings.

Escapement: A novel type of detent escapement. The brass escape wheel is well and lightly made, and thinned on both sides so that only the tips of the teeth remain the full height. It is held by two small screws on a brass collet on its arbor. Both impulse and discharge rollers are of brass, their acting surfaces set with pieces of steel crudely fixed and badly finished. The impulse surface leans markedly towards a radial to the tip. The tip of the discharge roller unlocking pallet is almost on the same radius as the impulse roller.

The detent is clamped on a fine wire of flat section, itself held in tension in a steel frame. The end of the steel frame is shaped round a steel boss in which is set the lower balance bearing, and held by two screws passing into the middle plate. The wire passes through a hole in the detent sufficiently large to admit two semicircular sections of brass as well, and there is a clamping screw set in the side of the detent. The locking stone is a half-round piece of polished steel, very rough, wedged in a hole by a piece of brass. The steel passing spring has a boss held by a screw on the underside of the detent, the free end of the spring presses against a pin at the nose of the detent. Banking for the detent is against an eccentric brass peg set in a hole in the edge of the steel frame under the detent, and secured by a brass nut.

Balance: Plain brass four-armed balance riveted to a brass collet on the staff. The staff pivots are remarkably large in diameter, about 0·45 mm, and made like train pivots. The bearings are simply pierced brass with flat steel endpieces. Diam. of rim 28·1 mm, h. 2·1 mm.

Balance spring: Grained steel helical spring of $5\frac{1}{2}$ open coils without teminal curves. There is apparently no thermal compensation and no means of bringing to time. The lower end of the spring is crudely bent in and pinned to a brass collet, the other end is pinned to a steel arm screwed on the balance cock.

Reserve of going indication: On the fusee arbor is pinned an index piece similar to that for a Geneva stop-work. This indexes a brass wheel with nine slots on the arbor carrying the indicator hand.

Going-train counts:
Great wheel (fusee) 84 teeth, 8 turns of groove
Centre pinion 12 leaves, wheel 96 teeth, 4 arms
Third pinion 12 leaves, wheel 90 teeth, 4 arms
Fourth pinion 12 leaves, wheel 8 teeth, 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 5 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 12 leaves, minute pinion 12 leaves, brass
Hour wheel 48 teeth, minute wheel 36 teeth

Provenance: In his inventory notebook, Ilbert records the acquisition of this machine from Jauncey in 1937. He assumed that the balance and spring were 'temporary' and mentioned that the machine was well made and of French or Swiss workmanship 'probably for aeroplanes' *c.* 1910. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1947).

Note: There is no clear evidence of country of origin or date, it could also have been made in Germany, the USA or even in Britain, but the design is reminiscent of the work of Berthoud and Motel. It would appear that some existing parts of high quality were used since the quality of the pinions and escape wheel is not consistent with the rest. It was probably being developed for use in aircraft. This would explain the avoidance of the fine pivots (because of vibration) and the aluminium parts (for reduction of weight).

III

OVERCOMING THE SHORTCOMINGS OF THE POWER SOURCE AND GEAR TRAIN

III.i (cat. nos 165–173)
ii (cat. nos 174–175)

(i) CONSTANT FORCE ESCAPEMENTS AND ESCAPEMENT REMONTOIRES
(ii) TRAIN REMONTOIRES

As the mainspring runs down the power varies, and as the gears rotate the power they transmit can also vary, the amount of this variation depending on the quality of the gears. Therefore, between windings the power to the controller, and thus the timekeeping, will change, and the amount of change will further depend on the quality of the controlling device.

If the mechanism is wound once a day then the timekeeping could vary throughout the whole day but the pattern of errors would repeat itself from day to day. If the mechanism is wound more frequently, then the variation during the day will be reduced because of the averaging that will occur. With more frequent winding there are fewer gears to introduce errors and the errors from this source will again be reduced. To make a timekeeper that is rewound frequently a practical proposition, the rewinding needs to be done automatically – that is, by the timekeeper itself. To this end the main source of power is made to rewind a secondary source which in portable timekeepers is a spring. This device, known as a *remontoire*, was invented by Jost Burgi in about 1585 (see Historical Introduction). The first portable *precision* timekeeper to incorporate a remontoire was that made by John Harrison who put his remontoire on the fourth wheel, the rewinding of the remontoire occurring every $7\frac{1}{2}$ seconds. The next step was a radical one – the incorporation of the constant force device into the escapement itself – thus this type of escapement is known as 'constant force'. Thomas Mudge invented and made the first successful constant force escapement, fitting it to his first marine timekeeper, cat. no. 165.

Despite the fact that it could be argued that timekeepers with constant force escapements or remontoires should not need fusees, of the eleven items in this section five have fusees: cat. nos 165, 166, 168, 170 and 174. Cat. nos 174 and 175 have train remontoires.

Constant force escapements can be divided into three main types:

1. spring pallet
2. hammer and nail
3. escapement remontoires

THE SPRING PALLET

Spring pallet escapements, although differing in detail, are all designed on the same basic principle. The escape wheel works in conjunction with a pair of spring-loaded arms, each arm being furnished with an inclined face which, when acted upon by an escape wheel tooth, resets the arm. Locking is accomplished by means of a knib or block on the end of the inclined pallet face. The balance acts with one arm at a time while the escape wheel is locked by the other. The balance is acted upon by the spring pressure on the arms which restrains it as the balance moves towards maximum excursion and impulses the balance as it returns towards its rest position. As the action proceeds the balance picks up the second arm and unlocks it. The other pallet is then acted upon by the wheel, being raised and then locking the wheel again. The impulse to the balance derives from the fact that the arm is acting upon the balance over a greater angle as it gives impulse than when it is acting against the balance.

There are only two examples of mechanisms containing this type of escapement in the collection, the one already mentioned by Mudge and one of the Mudge copies by Howells and Pennington whose escapement is now removed and replaced by a lever escapement. This would originally have been virtually identical to the Mudge.

The spring pallet escapement suffers from three disadvantages: it is not detached, it must be oiled at the pallets, and it operates over the entire arc and thus at the extremes of arc, the least favourable position where the interference to the isochronism of the balance and spring is at a maximum.

Additionally, variations in temperature can affect the properties of the springs, although it could be argued that the overall compensation might be able to take care of this effect.

THE HAMMER AND NAIL ESCAPEMENT

The hammer and nail escapement is so called because of the way in which impulse is given: a 'hammer' blow to the impulse pallet, the 'nail'. In some versions, notably Breguet's, the balance does not unlock the train and, in theory at least, one would expect this to be the perfect escapement. This is because it is completely detached, gives impulse on the line of centres and in some versions does not need to be lubricated on the impulse surfaces.

The first of these escapements, that by Charles Haley, was patented in 1796 (Patent No. 2132). This is mentioned by Gould (1923) who ventures to suggest that it was never satisfactory in action (p. 141). A movement containing this escapement is in the collection of the Worshipful Company of Clockmakers, inventory number 435.

Two years later, in 1798, Breguet patented his version (Patent No. 99) which is that to be found in his marine chronometer, cat. no. 167.

Others who used this type of escapement in marine chronometers are: De Lafons 1801, cat. no. 173; William Hardy *c.* 1810, Lego à l'Orient cat. no. 169; J. G. Ulrich 1825–8, cat. no. 170, whose version is the most complex of all; Joseph Bannister 1835, cat. no. 171; Louis Richard 1839; E. Couillaut, cat. no. 172; Hedgethorne *c.* 1899; Pettavel *c.* 1900; A. Potter *c.* 1900 and G. F. Cox *c.* 1912 (see *H.J.*, January 1913, p. 79). Pettavel's escapement has the distinction of being the only one of this type to be employed by another maker. It was fitted into a series of watches made by the firm of Paul Ditisheim. Simpler and more robust, it is said to have given excellent results even though fitted to watches and thus subject to far greater disturbances than the average marine chronometer.

The escapement has been revived recently by the Swiss Porte-Eschappement Company who used a variant of it with electrical rewinding for their Selticon clock (see *H.J.*, May 1961, pp. 294, 295, 296, 298).

This type of escapement almost always suffers from the risk of derangement due to accidental unlocking. The exception in the examples described in this section is that based on De Lafon's escapement. This is accomplished by virtue of the fact that the balance has to unlock the train; this of course means that the balance is no longer completely dissociated from the influence of the gear train.

ESCAPEMENT REMONTOIRES

Escapement remontoires employ a conventional escapement but the escape wheel is driven by a remontoire spring which is rewound by the train usually, but not necessarily, at each beat. It is thus effectively a train remontoire moved down to the very last wheel. An example of this is to be found in cat. no. 168.

The way in which the remontoire is rewound varies considerably in different examples. This type of mechanism can be made so as to be far less susceptible to derangement than the two previous types mentioned. Unfortunately nearly all the versions so far made have to be oiled where the escape wheel that gives impulse runs on the pinion arbor. Consequently the torque transmitted alters as the oil deteriorates or changes its characteristics due to other factors such as changes in temperature.

This problem has, however, been overcome with the Randall-Theurillat Escapement which uses a ball race and anti-friction rollers to support the remontoire wheel which can thus be kept clear of the escape wheel arbor. (See *Antiquarian Journal*, Autumn 1978, pp. 46–59, for an article by Anthony Randall about constant force escapements in general and the Randall-Theurillat Escapement in particular.)

The superiority of this type of escapement for ordinary applications where large variations in torque have to be allowed for is illustrated by the fact that this is the only form of constant force escapement in large-scale production. It is incorporated into a series of platform escapements made again by the Swiss firm Porte-Eschappement. This has been in use for decades and finds many applications.

Cat. no. 168 is signed *Gibbons Patent Remontoir*. The patent was, however, in the name of George Prior and is Patent No. 4214 of 29 January 1818.

Edward Massey also invented an escapement of this type, E. J. Dent took out a patent in March 1842 (No. 9302) for an escapement remontoire, and others who have developed such escapements in more recent times are Paul Ditisheim, Henry Jeanneret and Frederic Martin, these last three all in Switzerland.

III.i
CONSTANT FORCE ESCAPEMENTS AND ESCAPEMENT REMONTOIRES

165 THOMAS MUDGE (*c.* 1715–14 Nov. 1794)
1771–1774

MARINE TIMEPIECE *Plates 121c–f, 122–7*

Signature: On the back plate 'Tho^s Mudge Inv^t et fec^t London'.

Box: The mahogany outer carrying box is octagonal with two brass handles on opposite sides. The bottom is a brass plate with an eccentric winding hole covered by a circular escutcheon plate. Carefully joined separately moulded side panels, three sections of these panels are hinged and can be swung aside to remove the inner box. The hinged section has a latch that fits the lock beneath the carrying handle. The side panels are lined inside with faded red velvet and padded.

Inner box: In a letter to Count von Brühl dated 23 August 1774, Mudge states: 'I acknowledge it would have been better of brass. My only reason for making it of wood, was to save money, of which I have had, at no time, much to spare.'

The octagonal inner box (containing movement) is composed of many pieces of mahogany carefully and exquisitely made with overlapped joints and is light, strong and remarkably dust tight. The middle section is reinforced with two brass rings inside, above and below the windows. The inside of the middle section is turned and painted blue. The top glass is surrounded by delicately turned mouldings. The two sections are hinged with a push-piece operated catch at the front.

The catch has a downward-pointing tongue which engages with the catch and spring beneath the movement dial plate. The seven-knuckle hinge has a steel taper pin retained by brass screws.

The glazed bottom is pierced by a large hole taking a partially gilded circular escutcheon plate with eccentric hole for the key. The escutcheon plate assembly is retained by three screws. Detachable glazed bottom retained by plate in middle section which fits slots in bottom opposite a catch. Catch has recess with square for key. Middle section into rebated groove in top and bottom. Box presumably octagonal so that machine may be tested in any of the eight vertical positions.

Outer box: base 164 mm across flats, sides 146 mm across flats. Inner box: base 132 mm across flats, top 127·5 mm across flats, sides 120·5 mm across flats.

Dial and hands: Separate enamel dials show on left of centre minutes (in minutes of time and degrees) on right, hours (in hours and degrees) at top, reserve of going in days, and at the bottom, seconds. When the timekeeper is set to GMT then the time shown at local noon will indicate longitude.

The round dials are retained by moulded brass rings and the reserve of going dial by a moulded sector, and these and the silver decorative pieces are secured by small screws from the back. All visible surfaces of the dial and the fixing pieces are gilded. No repairers' marks are to be found anywhere on the dial or its parts.

Hands of blued steel.

Movement
Dial plate 114·3 mm across the flats, 106·6 mm across the raised circular portion; front plate diam. 107·3 mm; back plate diam. 107·4 mm; frame h. 34·9 mm.

Frame: Full plate construction with five turned, baluster shaped pillars, with square ends and riveted to the front plate. The dial plate is pinned to five short pillars also riveted to the bottom plate. The top or back plate, which is pinned to the pillars, carries another smaller bridge covering a large hole over the barrel. This small bridge carries the setting-up worm. The barrel is beneath a large hole but cannot be passed through it. Many of the smaller frame components are retained by brass screws. Pillars, main plates (except for underside of dial plate) and some of the smaller frame components gilded. The remontoire and balance potance are not gilded.

Fusee: Reversed but planted as normal so that each wheel in the train rotates in the opposite direction to normal. The dust-excluding pipe screwed to the back plate protects the winding square. The great wheel and the Harrison's maintaining ratchet are of brass with six crossings and are retained by a steel boss with four flats. This is an interference fit on its arbor. The brass winding ratchet has one click with a brass return spring. The stop-piece and maintaining detent springs are also brass. English stop-work with a lever system is controlled by a lever on the back plate, and can be swung in or out of the path of the fusee chain so that the machine can run for two or eight days.

Barrel assembly: This remarkable arrangement consists of two quite separate barrels which fit inside a drum that carries the fusee chain. The barrel arbor pivots in the barrel nearest to front plate and this is fixed inside the chain drum by three edge screws. The other barrel, badly distorted probably by mainspring breakage, is open at both ends. The back plate end carries a flange with skew-cut teeth that engage with the setting-up worm. These teeth rest in a narrow recess in the large hole in the back plate already mentioned. The upper end of the arbor pivots in a cover plate that retains the open barrel and the lower end of the arbor pivots in the front plate (see fig. 11).

When the worm is rotated both springs move since they have a common 'live' arbor. On rotating the upper barrel one turn, assuming springs of equal strength, each barrel will rotate half a turn. Looking down on the back plate the upper spring coils clockwise and the lower anticlockwise (from centre to outside).

Although it is not possible to be sure of Mudge's reasons for using this design of barrel end spring it is at least possible to predict the results by comparing a barrel with a single spring to Mudge's arrangement.

Applying the formula for the maximum torque available from a given spring which is:

$$T_{\max} = \frac{\theta(Eht^3)}{12l}$$

where θ is the effective angle through which the spring is bent, i.e. in this case the effective number of turns of winding; E is Young's modulus (the same for both); h is the height, t the

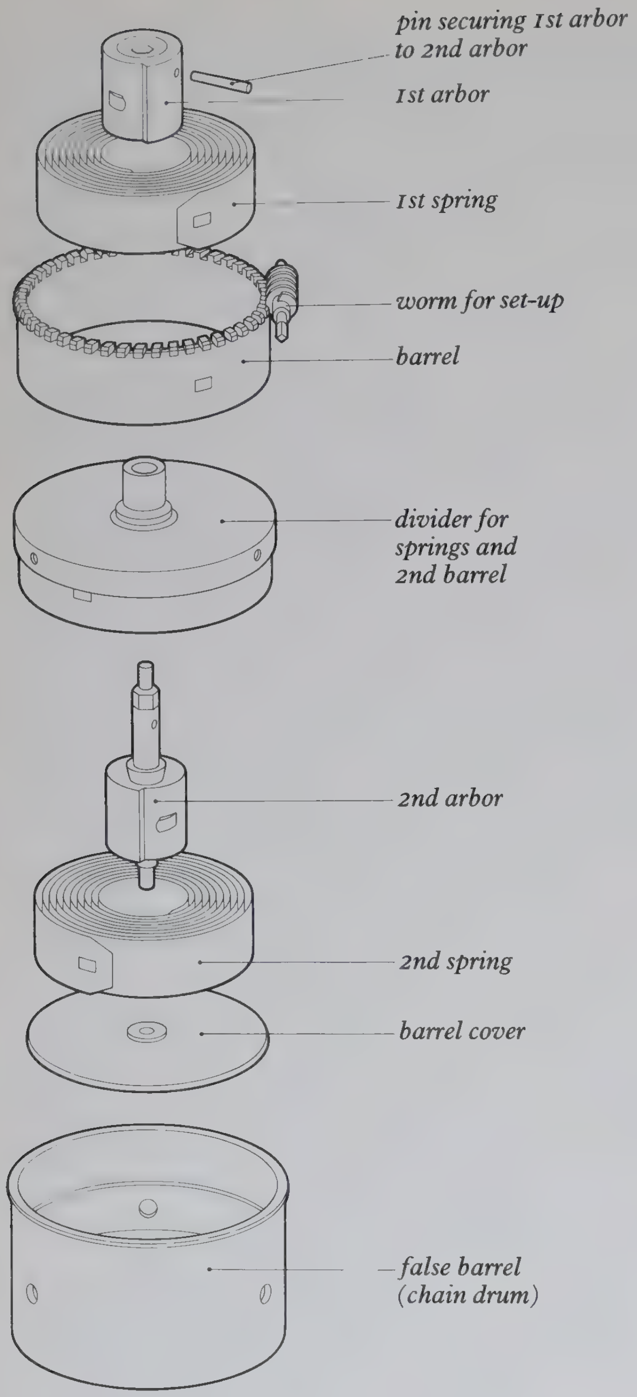

pin securing 1st arbor to 2nd arbor
1st arbor
1st spring
worm for set-up
barrel
divider for springs and 2nd barrel
2nd arbor
2nd spring
barrel cover
false barrel (chain drum)

FIGURE 11
Barrel arrangement in Thomas Mudge's marine chronometer

thickness (the same for both springs, i.e. *the maximum for the barrel according to the classical criteria*) and l the length of the one spring

$$\text{A} \qquad T_{\max} = \frac{\theta(E \times h \times t^3)}{12l}$$

Although there are two springs in Mudge's arrangement they must be treated as *one* in the calculation and the formula becomes:

$$\text{B} \qquad T_{\max} = 2\theta(\text{twice the turns}) \frac{E \times \tfrac{1}{2}h(\text{half the height}) \times t^3}{12 \times 2l(\text{twice the length})}$$

Removing all the identical terms from both, the result in formula A becomes $T_{\max} = l$ and in Formula B, $T_{\max} = \frac{1}{2}$. $T_{\max}$ for the double spring arrangement then is only half that achieved for the single spring. This is the result that one would expect. There is no magic that can produce more *total* stored energy from a given barrel volume than is obtained by applying the classical rules.

The only choice one has is in how the stored energy is released, namely either as a lower maximum torque and many turns or as a higher maximum torque and fewer turns. Normally obtaining more turns than given by the classical formula would be at the expense of a lower overall power output and would mean using a thinner spring than given by the classical formula. This leads to an overall greater loss of power because of intercoil friction which ironically can be used to produce a more constant torque output, a fact that can be very useful in a going barrel design. There is, apparently, no advantage though when a fusee is employed for this can do the job of equalling the torque provided by the spring.

With Mudge's arrangement more turns have been achieved without encountering the problem of the greater intercoil frictional losses that occur with thin springs. This is because the springs are the same in all respects except height to that which would be obtained as a result of applying the classical formula.

The loss in the system comes from the reduction in the available height and barrel diameter but to offset this there are two gains: the lower frictional losses at the barrel and fusee pivots and since there is a greater reduction at the barrel stage there is less need for reduction in the gear train with a corresponding increase in efficiency. Although the latter saving is not probably of any great consequence the losses at the barrel and fusee pivots are much larger than is normally appreciated and can be so great at times that the barrel pivots can seize. It is significant that in some high-class American watches the mainsprings are unexpectedly thin. It is quite likely that the reason for this is the use in these watches of an arrangement that gives lower frictional losses than usual at the barrel (for details see Chamberlain 1941, Chap. 15).

Another gain that is not so obvious results from the need for a lower reduction in the gear train. Obviously all else being equal if twice the number of turns are available at the barrel then the reduction ratio in the gear train for unit torque at the escapement needs to be half what it would normally be. This again will lead to lower frictional losses.

Going train: The high count train has arbors with a high standard of polish. The centre arbor, undercut to prevent oil spread from the pivot in the front plate, but all other pinions have flat polished ends. Pinions are slightly rounded at ends from polishing process. Wheels made and finished well with light crossings as well as flat surfaces polished. The wheels reduce in thickness from the central boss to the edge. The strong, light and elegant contrate wheel has crossings that taper in both width and thickness from centre to edge.

Both centre and third arbors appear to be made of two pieces carefully fitted together. The centre wheel is riveted to its arbor, the third and contrate wheels have brass collets. A small wheel on the fourth arbor drives another similar wheel on the arbor that carries the seconds hand so that this can revolve in usual direction. This is necessary because the fourth arbor rotates in the reverse direction to normal.

Jewelling: The lower pivot of the fusee arbor runs in a large brass bush, the upper directly in a hole in the back plate. The third arbor pivots in detachable brass bushes retained by brass endplates, these being hollowed to prevent drawing of oil from the bearing. Brass fourth arbor bearings are retained by steel endplates.

The escape arbor pivots and those of the two pivoted constant force pallet arms run in pierced jewels. The outer pallet arm pivots have steel endplates and the escape arbor pivot has an endstone at the end remote from the balance staff.

The balance staff pivots are large at 40/100 mm diam. with the end that rests on the diamond endstone shaped to a pointed cone. The side thrust from each pivot is taken by four anti-friction rollers which are pivoted in cages mounted on the balance cock and the potance. These rollers are planted so that the pivots of one set are displaced radially by 45° with respect to the other set.

Escapement: Mudge's constant force escapement in which impulse to the balance is given alternately by one or other of two spiral springs. Each of these springs is attached to a pivoted arm that contacts a pin on the balance staff. Also carried on the arbor of each pivoted arm is a curved steel pallet to receive impulse from the escape wheel teeth. The pallets end in a nib which locks the tooth on the escape wheel. Each of these pallets has a deep score mark where the escape teeth have rubbed.

The balance and its two balance springs, together with the two pivoted arms and their spiral springs, make up a system which is isolated from the going train except at the moment of unlocking. The amount of energy taken from the system at unlocking is dependent on that supplied through the train. Otherwise the only variable in the system is the state of oil in the pivot holes. Since there are no less than twenty of these within the system, excluding the balance pivots acting on the diamond endstones, the state of the oil must have a significant effect on the rate. In addition, the pallets probably need to be oiled.

One of the upper set of anti-friction rollers has a pronounced nick in its edge, suggesting that at some time its pivots have seized solid. The balance pivot is also slightly marked. There is also quite considerable play of the balance pivot between the upper rollers, and this is more in one direction than another. The brass pins on the balance staff receiving impulse from the pivoted arms show signs of rubbing. This is probably due to the greater freedom of the balance staff pivots as opposed to that of the arm pivots, but could also indicate that these six pivots are not exactly planted on the same centre line. For a full and complete description of the escapement see R. Good, 'Pioneers of Precision Timekeeping', *Antiquarian Horological Society*, pp. 75–91, n.d., also Gould 1923, pp. 77–9.

Balance: Plain brass three-armed balance of large diameter and thin section. One of the arms has an enlarged almost circular portion near the boss to counterpoise the cranked part of the balance staff. It is secured to a boss on the balance staff by two screws.

Balance spring: Two open coiled spiral springs are fitted, one above and one below the balance. Each has a long straight portion towards its stud, and they are coiled in the same direction, clockwise from the collet. The thermal compensation device acts on the lower spring, the mean time adjustment on the upper one, in both instances this is carried out on the straight part of the spring. The mean time adjustment is made by rotating the squared arbor on the left-hand end of the balance bridge, the thimble has a vernier working with a fixed concentric drum. A brass carriage carries the adjustable index pins. The lower spring is of $4\frac{1}{4}$ turns, excluding the straight part, the upper one similar or slightly less, they are tempered to a brownish purple and have been reduced in thickness on the straight part towards the stud. This was one of Mudge's methods of making isochronal adjustments. The index pins could also be moved towards or away from each other. He also altered the set up of the constant force spiral springs and there are dot marks on the brass jewel settings over each spring to give a reference for this. In a letter to his patron Count von Brühl on 11 January 1774, Mudge stated that he had adjusted the machine to have a variation of rate of two seconds in twenty-four hours with a variation in semi-amplitude of 30°. In another letter, dated 15 November 1774, he mentions the effects of barometric error and relative humidity and although he cannot envisage their elimination considers that they may often cancel each other out.

Thermal compensation device: Two bimetallic laminae are fixed in a straight line with their free ends crossing over each other. Each carries a brass pin at its free extremity resting on one or other of two arms forming part of a block on a pivoted arbor. Looking at the device, the laminae can be distinguished by the small brass rivets holding the brass and steel together. The left-hand one has the brass on the outside and the steel inside, the right-hand one the opposite. Also carried on the pivoted arbor are an arm with index pins to embrace the lower balance spring, with a kink where it passes round the balance staff, and a pointed tail passing over an engraved silver scale. The fixed ends of the laminae are held with screws on a double slide. This has a double threaded arbor with squared end to move the slides towards or away from each other to vary the amount of compensation obtained. The whole assembly is carried on an L-shaped base secured to the back plate, and having one round and one square steady pin. All the brass parts are gilded. Although very ingenious and beautifully made, this system was found to be sluggish in action.

Balance bridge: The decoration is rather inelegant when compared with other eighteenth-century horological work, especially that of the great English masters. This is partially explained in a letter from Mudge to Count von Brühl on 5 October 1775, in which he mentions that a larger balance has been made and other alterations carried out. He thought the first too small and heavy. He also made a third balance 1/10″ bigger than the first and nearly 4/10″ smaller than the last. These two balances being screwed to the staff were interchangeable and thus comparisons could be made between them.

Mudge comments on the time and trouble he had had making a new cock and associated pieces '... I shall let the cock [bridge] go without its usual ornaments of graving and gilding, as I am loth to spend any more money upon it, or so much time.... '.

The holes for the original bridge survive on the back plate near the third and fourth arbor bearings and on the barrel bridge. The latter must have been on a piece fixed to the barrel bridge. When this was removed it left behind an impression marked by a break in the gilding. This is normally covered by an extension of the graduated sector under the balance, obviously made so as to hide it.

A point of especial interest is the 'safety' piece held by a shoulder screw from underneath. Its use was for a long time obscure. The claw-shaped end embraces the stud of the upper balance spring and the disc on the end of the tail covers a screw securing the foot of the balance bridge to the table. In the original arrangement this piece was a safety device to make it impossible for the bridge to be removed until the stud had been freed and pushed down through the shaped hole in front of it, after which the brass piece could be swung aside to reveal the screw. Without these precautions inadvertent removal of the bridge without freeing the stud could cause distortion of the upper balance spring.

With the 'new' balance bridge Mudge used the old bridge securing screws for the feet and other screws to secure the feet themselves to the back plate. However the safety piece was preserved, and it is remarkable that it was also fitted to several of the copies made for Mudge's son by Howells, Pennington, Pendleton and others, although it had no purpose. At best it could only have served as a reminder to free the stud before removing the bridge.

Mean time adjustment: This assembly is mounted on the top of the balance bridge with the two steel arms carrying the index pins screwed on the underside. It can be moved towards or away from the upper balance spring stud by rotating the squared shaft carrying a graduated thimble and only acts on the straight portion of the upper spring. Note that the steel steady pins of the steel arms are fitted in slots so that they can be moved for making isochronal adjustments. In the copies made for Mudge junior a better, easier and more positive arrangement was used to effect these adjustments.

Going-train counts:
Great wheel (fusee) 108 teeth, 12 turns of groove
Centre pinion 12 leaves, wheel 128 teeth, 6 arms, 1 turn per $106\frac{2}{3}$ minutes
Third pinion 12 leaves, wheel 120 teeth, 6 arms, 1 turn per 10 minutes
Fourth pinion 12 leaves, wheel 120 teeth, 6 arms, 1 turn per minute
Escape pinion 12 leaves, wheel 15 teeth, 5 arms
Beats per hour: 18,000

The idle wheel on the seconds arbor has 45 teeth, 4 arms, and is driven by another similar on the fourth arbor.

Up-and-down indicator: A brass pinion of 7 leaves on the end of the fusee arbor meshes with a wheel of 48 teeth carrying a brass pinion of 14 leaves. This last pinion meshes with a counterpoised sector of 27 teeth, on the arbor of which is carried the indicator hand.

Motion work:
The centre arbor carries a brass wheel, friction tight for hand-setting, of 80 teeth, meshing with another of 45 carrying the minute hand and rotating once per hour.
The fourth arbor turns once per minute since it drives the seconds hand via a 1:1 ratio gearing.
The third arbor turns in $\frac{120}{12} = 10$ minutes
The centre arbor turns in $\frac{128}{12} \times 10$ minutes ($= 106\frac{2}{3}$ minutes)
The wheel of 80 also turns in $\frac{128}{12} \times 10$ minutes
The wheel of 45 therefore turns once in $\frac{45}{80}$ of $\frac{128}{12} \times 10$ minutes = 60 minutes
The motion whel of 80 also carries a pinion of 8 leaves meshing with the hour wheel of 108 teeth turning once in 24 hours
The pinion of 8 carried on the wheel of 80, turns once in $\frac{128}{12} \times \frac{10}{60}$ hours
The wheel of 108 must turn once in $\frac{128}{12} \times \frac{10}{60} \times \frac{108}{8}$ hours = 24 hours

This is, of course, a most surprising and unusual arrangement of the gearing. A partial explanation is that with a comparatively slow rotation of the centre arbor the great wheel to centre pinion gearing and the number of turns of the fusee can be reduced, as compared with what they would need to be if the centre arbor turned once in twelve hours. However if the centre arbor period had been further increased to one turn in 120 minutes instead of $106\frac{2}{3}$, another seemingly logical solution, this would have increased the ratios necessary in the going train. One can only assume that the arrangement is a compromise. Certainly Mudge had very good reasons for what he did, even if his precise motives now escape us.

Balance brake: Between the balance and the edge of the back plate is a large slot mostly filled by an insert but leaving a sector-shaped hole. There is also a hole near this with a rubbed ring where an arbor has pivoted. This was probably for a brake lever operating on the edge of the balance, and activated perhaps by the fusee chain. It appears to have been discarded during construction of the machine, probably when the going was reduced from eight to two days.

Provenance: Thomas Mudge constructed this chronometer between about 1771 and 1774. It was tested at the Royal Observatory, Greenwich from 14 December 1774 to 12 March 1775, when it stopped with a broken mainspring. It was repaired by Mudge and retested from 11 November 1776 to 26 February 1778 when the mainspring broke again. After the second breakage Mudge modified the stop-work to use only the first two days of wind. After his death in 1794, the chronometer remained in the possession of Mudge's friend and patron John Maurice, Count von Brühl (1736–1809), Envoy of the Kingdom of Saxony to the Court of St James's from 1764 until his death.

There is a letter from a dealer in works of art and virtue, W. Forster, to the Rev. Walter Mallock dated 17 July 1843, preserved in a copy of a booklet, *Description of the plates of Mr. Mudge's Time-keeper*, by Robert Pennington. Forster states that he purchased the chronometer at a sale in Great Marlborough Street, London, in 1807 and sold it to the Duke of Sussex. At a sale of the Duke's effects at Christie's he bought it back. His purpose in writing to the Rev. Mallock was to offer the latter the chronometer for twenty-one guineas, as he had had another offer of sixteen guineas for it from a Mr Emery.

The chronometer remained in the Mallock family until 1933 when Ilbert purchased it and the Mudge lever clock from Miss Helena Mallock. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1946).

Exhibited: British Clockmakers' Heritage, Science Museum, London, May–September 1952; British Watches and Clocks, City of Birmingham Museum of Science and Industry, October 1953–February 1954; Masterpieces of British Art and Craftsmanship, Ormeley Lodge, Ham Common, Surrey, July 1954; Five Centuries of British Timekeeping, Goldsmiths' Hall, London, October 1955; Pendulum to Atom under the auspices of the Worshipful Company of Clockmakers at Goldsmiths' Hall, London October 1958.

Note

Official and unofficial trials of Mudge's No. 1 Timekeeper (extracted from a narrative of facts by T. Mudge jun.).

25th June 1774	Mr Dutton attended with No 1 to have it tried at Greenwich
14th December 1774	Start of the first trial at Greenwich
12th March 1775	No 1 stopped with a broken mainspring
11th November 1776	No 1's test resumed at Greenwich
26th February 1778	No 1 again stopped with a broken mainspring

Board of Longitude Minutes, 1st March 1777:

> Dr Maskelyne (Astronomer Royal), stated that No 1 during tests had gained 1 minute 19 seconds in 109 days 'and that it is greatly Superior in point of accuracy to any timekeeper which hath come under my inspection.' Mudge was awarded £500.

		Mean Rate/day
20th June 1776 –31st October 1776	by Dr Hornsby at Oxford	−1·231 secs.
12th November 1776 –30th November 1777	by Dr Maskelyne at Greenwich	+2·771 secs.
18th April 1780 –7th May 1781	by Count Bruhl	−2·396 secs.
Admiral Campbell's first voyage to Newfoundland (175 days)		+0·51 secs.
Admiral Campbell's second voyage to Newfoundland (138 days)		−0·636 secs.
5th December 1785 –29th May 1786	by Count Bruhl	−0·639 secs.
29th June 1786 –9th October 1786	by Mr Zach whilst travelling in Europe	+0·141 secs.
20th May 1789 –5th October 1789	by Count Bruhl	+0·280 secs.
2nd February 1791 –30th September 1792	by Count Bruhl	−1·608 secs.
30th September 1792 –8th December 1792	by Count Bruhl	−1·70 secs.
21st December 1792 –21st May 1793	by Count Bruhl	+1·427 secs.

Between 5th December 1785 and 5th December 1789 the machine was neither cleaned nor adjusted.

In 1776 No 1 was also tested by His Majesty King George III at his private observatory, the records of this test have not yet come to light. In the same year Mudge received the Royal Appointment.

There is a somewhat related piece, a marine timepiece by Josiah Emery, No. 1, made *c.* 1792 (one of four), which is in the collection of the Worshipful Company of Clockmakers and contains an escapement based on Mudge's constant force escapement. In it, however, the functions of locking and recocking are dissociated, locking being performed by a separate lever.

A full description of this marine timekeeper, which was submitted for trial at Greenwich with No. 2, is to be found in *AH*, June 1961, pp. 206–7.

Bibliography: Thomas Mudge, *Thoughts on the means of improving watches*, London, 1765; Count von Brühl, *A register of one of Mr. Mudge's timekeepers*, London 1771; Thomas Mudge, *Register of the going of Mr. Mudge's first timekeeper for April 1780–May 1781*, London, 1781; Count von Brühl, *Three registers of a pocket-chronometer. With an account of the first Mr. Mudge's timekeepers by Vice Admiral Campbell in a voyage to and from Newfoundland*, London, 1784; id., *A reply to Rev. Dr Maskelyne*, London, 1792; Thomas Mudge, jun., *Memoirs of the life and mechanical labours of the late Mr. Thomas Mudge with portrait*, London, 1792; id., *A Narrative of Facts*, London, 1792; id., *Report on the select committee of the House of Commons to make enquiry into the principles on which the Mudges' timekeepers have been constructed*, London, 1793; id., *Description with Plates of Mr. Mudge's Time-keeper*, London, 1799; Gould 1923, pp. 77–9; Chamberlain 1941; Cecil Clutton, 'Josiah Emery's No 1 Marine Timekeeper', *AH*, June 1961, pp. 206–7; Richard Good, 'Pioneers of Precision Timekeeping', *AH*, n.d., pp. 75–91.

166 HOWELLS AND PENNINGTON

1793–4

MARINE TIMEPIECE *Plates 128–9*

Signature: 'Howells and Pennington No. 1 FOR Tho^s Mudge'.

Case: The movement contained in a gilded brass box with eight turned pillars, the top and bottom glazed, the sides with eight glazed panels. Top 138 mm diam., bottom 142 mm diam., overall h. 79·5 mm, h. of brass frame 66·3 mm.

Dial and hands: Similar to Thomas Mudge, cat. no. 165. The gilded brass disc on which the small dials are mounted is fixed with four locking screws to a turned ring with five turned feet held with pins to the front plate. The disc and ring are punched with the number 3.

Movement

Plate carrying the dials 109·5 mm; dial ring 126·3 mm; front plate diam. 107·5 mm; back plate diam. 107·4 mm; frame h. 36·1 mm.

Frame: Full plate construction with four turned pillars, similar to that of cat. no. 165 but the pillars much less elegant. Both plates are pierced by holes on the balance centre line, the brass components are gilded. The balance potance and remontoire assembly have been removed and replaced by a brass plate and three steel pillars, for a lever escapement.

The underside of the balance bridge and compensation unit are both punched with the number 3, also both plates on the inside of the frame, and the inside of the dial plate.

Fusee assembly: Similar to that of cat. no. 165 with the following exceptions:

The barrel towards the back plate has ratchet-shaped teeth on its upper edge and these are sandwiched between a brass ring and a recess in the back plate. A brass setting-up click on the back plate has a block at its acting end passing through a slot in the plate to engage with the ratchet teeth. The lower barrel is integral with the outside cylinder on which the chain is wound and not a detachable unit.

Both mainspring are signed 'Geo. Answell May 1795'. The great wheel teeth show signs of wear.

Stop-work: On the front plate there is the remains of a similar system to that fitted in cat. no. 165 to activate the stop-work for either two or eight days running. The pillar that once carried a pivoted arm and an indicator on the dial side of the front plate are all that remain.

Going train: The fourth wheel is a later replacement for the original contrate wheel. The fourth pinion is hollow and an interference fit on the arbor, and both are polished. The centre and third arbors are smooth grained but not polished, the centre pinion being integral with it arbor, the third is hollow and fitted like the fourth. The centre and third wheels are thicker at the boss than the rim. The fourth wheel is the opposite. The quality and finish are not as good as those of cat. no. 165.

Jewelling: The fourth arbor and balance staff pivots run in pierced jewels with endstones. The original diamond endstone and four anti-friction brass roller assembly remain on the balance bridge but have no function. The jewelling for the upper balance staff pivot is fitted in a separate plate attached to the underside of the balance bridge.

Escapement: The holes for two conical-headed fixing screws and a shoulder screw for the original constant force escapement block remain. The present escapement is a ratchet-tooth lever with table roller, the wheel of brass, the other parts polished steel with jewelled pallets and impulse pin.

Balance: Small light gilded brass three-armed balance, the rim reduced on the underside to further lighten it. The diameter is about two-thirds that of the original balance and demonstrates clearly the mechanical inefficiency of the lever escapement compared with Mudge's constant force escapement, though some allowance must be made for the balance staff pivots carried in ordinary jewelling.

Balance spring: Blued steel spiral spring of 9½ turns, fitted between the balance and the back plate and pinned to the same block as the original lower balance spring. The thermal compensation device has been modified to act as an index. The original upper balance spring has been completely removed, leaving only a later brass stud not drilled for the spring, and the index system. An adjustable pin could be moved towards or away from the upper spring in a circular path, independent of the other which could be traversed along the spring by means of the original index system, still in place.

Thermal compensation device: Similar in principle to that of cat. no. 165 but with the following detailed differences. The bimetallic strips have independent means to move the free ends towards or away from the pivoting point of the lever system. The free end of each strip is of brass shaped to pass round the arbor carrying the beaks on which the ends of the strips act.

Seen from the back the left-hand strip has been bent so that it no longer acts, the right-hand one has been bent so as to bear more heavily and biases the pivoted lever in a clockwise direction. The beak for the left-hand strip has also been shortened. A steel screw set in a block screwed to the underside of the temperature scale has been added so that it bears against the indicator tail. Movement of the screw causes movement of the pivoted assembly whose function has become one of an index to shorten or lengthen the effective length of the single balance spring.

Going-train counts:
Great wheel (fusee) 108 teeth, 12 turns of groove
Centre pinion 12 leaves, wheel 128 teeth, 6 arms
Third pinion 12 leaves, wheel 120 teeth, 6 arms
Fourth pinion 12 leaves, wheel 120 teeth, 6 arms
Escape pinion 12 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

The idle wheel on the seconds arbor has 36 teeth, and is driven by another similar on the fourth arbor

Up-and-down indicator: A brass pinion of 7 leaves on the end of the fusee arbor meshes with a wheel of 48 teeth carrying a wheel of 14 leaves. This last pinion meshes with a counterpoised sector of 26 teeth, carrying the indicator hand on its arbor. Concentric with the sector arbor is a squared shaft ending in a yoke. The yoke embraces the lever operating the two or eight day stop-work. On the square of the shaft is a hand passing over the up-and-down dial which can be used to set the stop-work as shown on the dial.

Motion work: The offset centre arbor carries a wheel and pinion friction tight. The wheel of 80 meshes with another of 45 carrying the minute hand. The brass pinion of 8 leaves meshes with a wheel of 108 teeth carrying the hand making one turn in 24 hours.

Provenance: Bequeathed by C. A. W. Boothroyd in 1978 (reg. no. 1978, 12-4, 1).

Note: This machine, made to the order of Thomas Mudge junior as a copy of his father's marine timekeeper, was ordered by the Duke of Saxony but not delivered as it was unsatisfactory. Thomas Mudge Senior lived to see it before he died in 1794, manufacturing having started in 1793 after the award of £3,000. The machine is illustrated in the portrait of Count von Brühl.

Over 20 of these copies were made, some carrying the name 'Howells Pennington', a few the name 'Howells Barraud Jameson', but the majority carry the name 'Pennington Pendleton and others'. Although most of these copies are in a bad state three are in a good and original state:

No. 7 'Howells Pennington' made in 1795 is now in the collection of the Worshipful Company of Clockmakers, London.

No. 9 'Howells Barraud Jameson' made in 1796 is now at the Headquarters of the British Horological Institute, Upton, near Newark in Nottinghamshire.

No. 10 signed 'Howells Pennington' is now in the Sir John Soane Museum, London.

Others are:

No. 3 of 1795 by 'Howells and Pennington' is privately owned.

No. 4 signed 'Howells and Pennington' is at the Maritime Museum as is No. 12 by 'Pennington Pendleton and Others' of 1796.

No. 10 by Howells Barraud and Jameson of 1796 (note there are two number 10s) is at the Royal Observatory Herstmonceux, Sussex.

No. 14 is at the Smithsonian Institution in Washington, USA and is presumably by 'Pennington Pendleton and Others'.

Of the remainder, by 'Pennington Pendleton and Others', the whereabouts of No. 17 (1797) and No. 18 (1796) is unknown, Nos 22 and 24 are privately owned, and No. 26 is in the Time Museum, Rockford USA.

Bibliography: Cedric Jagger, in *Paul Phillip Barraud 1750–1929*, London, 1968; discusses these copies, pp. 19–30, 52–3. On p. 27 he says:

> Many of these, of course, are not in original condition; usually the escapement has been altered. Nos. 1, 4, 10 (Pennington, Pendleton version) and 26 were eight-day instruments, and maybe there were others. No. 17 obviously got badly out of turn in the chronology of manufacture; one assumes it gave trouble, and maybe most of the year 1797 was given over to sorting out similar 'problem children'. Pennington, Pendleton no. 10 – which was made for the Duke of Marlborough – appears to be unique in possessing an inscription round the dial, reading: 'Invented by Tho. Mudge for the benefit of navigation and rewarded by the British Parliament Anno Do. 1793'. One is tempted to speculate that this may have been added to distinguish it from the rival no. 10; as also that no. 2, should it ever turn up, ought to carry the date 1794, as it was the first to be finished.

167 BREGUET

c. 1800

MARINE CHRONOMETER *Plates 130–1*

Signature: On the dial 'Breguet No 428'.

Box: The movement contained in a brass canister, the top half sliding into the bottom, and with a bayonet fixing and a single locking screw. Both ends of the canister are glazed, and there is a small brass levelling weight screwed to the edge of the bottom. The bottom half of the canister is gimballed in an oak box. The gimbal ring is square, with rounded corners, and there is no lock, it is pivoted on brass screws set in the wood of the side of the box, with their ends formed into pivots. There is a tipsy key numbered 4847, fitted in a corner. The sides of the box are fitted together with dovetail joints, and there is a sliding panel over a circular aperture in the top with an inset diamond-shaped brass plate numbered 426. The box has the usual lock and carrying handles, and there is a brass limit stop for the top, fitted on the outside. Base 208 mm square, sides 204 mm square, h. 187 mm.

Dial and hands: The dial a heavy brass plate, engraved and silvered on a granular surface, the engraving filled with black wax. The dial is attached directly to the front plate by four turned pillars and pins, leaving room for the under dial work, at the back it is engraved or punched 428. The indications are as follows: the three large central dials, starting at the top and going round clockwise, are for seconds, minutes and hours. The sector at the bottom is for reserve of going and the small dial below this records each time the machine is wound. The sector on the upper left-hand side indicates temperature, and the small dial beneath the hand indicates each time the temperature rises above a certain value. The right-hand small dial hand advances one division each time the machine is twisted as in starting. Winding and hand setting are controlled by two squared arbors of different sizes, through the dial and holes in the glass; these holes are normally covered by brass caps.

Hands are of blued steel.

Movement

Front plate diam. 100·3 mm; middle plate diam. 100·3 mm; back plate diam. 100·3 mm; frame h. over the front and middle plates 37·3 mm; frame h. over the middle and back plates 19·1 mm; frame h. over the front and back plates 53·5 mm.

Frame: Built up in two layers. The front and middle plates are separated by four cylindrical pillars riveted to the middle plate and with the front plate held by pins. Between these plates are planted the two barrels, the winding work and the going train, as far as and including the fourth arbor. All the escapement and balance components are planted on the back plate between a series of cocks and potances and the plate. The back plate has four cylindrical pillars which pass into holes in the middle plate, which is retained by taper pins. Each plate is numbered 428.

Going barrels: Each drives the centre arbor. Each barrel arbor carries a large brass winding wheel which meshes with a common steel wheel on the winding arbor having a steel click pivoted in the frame. Breguet's stop-work is fitted on one barrel cover, the reserve of going indicator operating mechanism on the other. The latter mechanism is similar to that described for Breguet et fils No. 2741, cat. no. 130, except that the nut moving up and down on the threaded piece on the barrel arbor is cone-shaped and brass (see figs 12 and 12a). The arm, spring loaded against the side of the cone, moves towards or away from the arbor as the cone moves up and down. This motion is transferred to a toothed sector engaging with another on which the indicating hand is carried. Stop-work is also incorporated in the reserve of going operation mechanism, so that each mainspring can be set up a pre-determined amount. The mainspring in the barrel with reserve of going is marked 'D Juin '67'. It is hooked with an eye to a steel hook piece held by a screw to the barrel wall partly in a rectangular slot as for solid hooking. The arbor has a brass unsnailed boss and steel hook. The other barrel is allowed four turns of going by its stop-work and is set up $4\frac{1}{2}$ turns. Its spring is also signed 'D Juin '67', otherwise it resembles the other in every detail. Each spring has a bride. The barrel with reserve of going indication has had two teeth carefully replaced.

Going train: The centre arbor is planted at the centre but

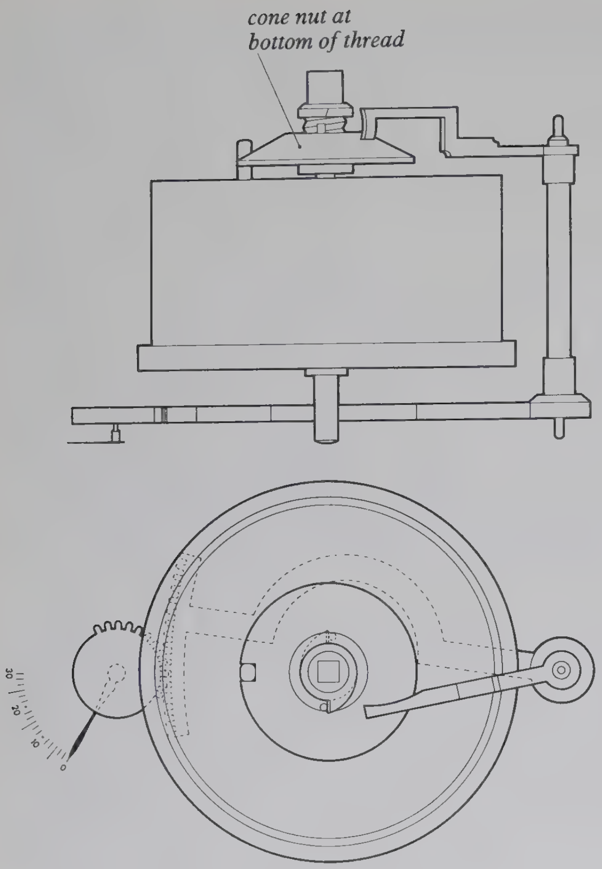


FIGURE 12
A. L. Breguet's form of 'up and down' work – fully wound condition

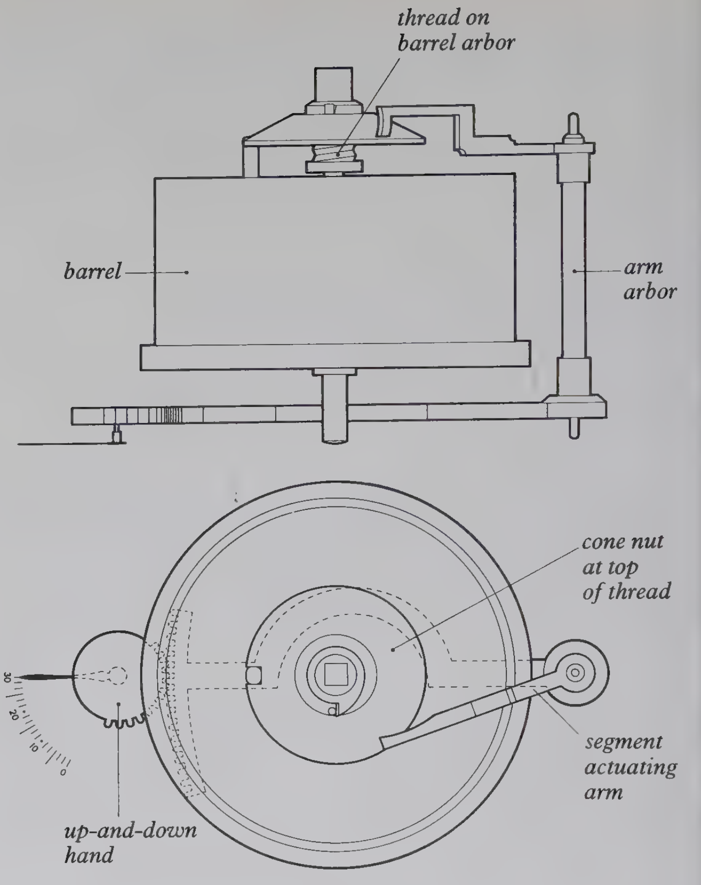


FIGURE 12A
A. L. Breguet's form of 'up and down' work – run down condition

does not drive the motion work or any of the hands. These are driven by a pinion on the third arbor meshing with the wheel turning once per hour and carrying the minute hand. The centre and fourth wheels are riveted to their pinions, the third to a collet on its arbor. The general quality of the finish is good without being remarkable.

Jewelling: Only the pivots of the escapement run in jewelled bearings. The balance staff has conical pivots running in the usual jewelled holes with endstones. The remontoire wheel and fly arbor pivots run in pierced jewels, but the pivoted remontoire detent has tapered pivots with flattened ends running in blind holes in pieces of ruby. The pieces of ruby are set in detachable brass strips, the one on the inside of the frame with an endshake adjusting screw.

Escapement: An example of Breguet's constant force escapement employing three detents. A pivoted counter-poised detent has a gold helical spring with terminal curves colleted to its arbor, and is held locked on the locking stone of a conventional spring detent having banking and a passing spring. The latter detent is released by a roller on the balance staff at the correct moment for the pivoted detent to be released in its turn, to transmit impulse to the balance. The free acting end of the pivoted detent is formed into a crescent, at the far end of which is set a piece of ruby. This piece of ruby contacts a gold block set on an arm attached to and curving round the balance staff. At the end of impulse the end of the pivoted detent encounters the end of a third detent on which is locked a fly. The fly is the last pinion of the going train, and is driven by a wheel on whose arbor is carried the rewinding wheel which has a series of teeth with cycloidal acting surfaces to rewind the pivoted detent. They act on a piece of ruby set in a short piece standing off the crescent of the pivoted detent.

The gold helical remontoire spring has a certain set up that can by varied by moving a pointer to which it is fixed over a scale. There are also several screws for adjusting the different functions (see also Gould 1923, p. 142).

The whole escapement and balance assembly is mounted on a separate plate and can be removed as a unit. A screw is provided that operates a fourth wheel lock that should be engaged before this plate is removed.

Balance: Bimetallic two-armed balance of Arnold 'z' type. The bimetallic rim sections each secured by two steel screws to an upstanding integral brass block on the end of the brass crossbar. Brass quarter nuts are fitted on studs, and brass double slotted screws on top at the ends of the arms. At the free end of each rim section is fixed a short steel piece with three tapped holes for a small brass screw to adjust the compensation. The balance is secured by two screws to a brass collet on the staff. Diam. of rim 35·1 mm, h. 3·5 mm.

Balance spring: Blued steel helical spring of 8 turns, with terminal curves. The brass collet has a slotted counterpoising tail, and a clamping screw for the collet on the staff. The stud is clamped under a steel strip on a brass stand having three levelling screws and a central clamping screw.

Going-train counts:

Great wheels, each 120 teeth, one turn in 10½ hours, the stop-work allowing four turns of going

Centre pinion 8 leaves, wheel 84 teeth, 4 arms, 1 turn per 42 minutes

Third pinion 12 leaves, wheel 72 teeth, 4 arms, 1 turn per 6 minutes

Fourth pinion 12 leaves, wheel 75 teeth, 4 arms, 1 turn per minute

Escape pinion 10 leaves, wheel 16 teeth, 4 arms

On the arbor of the escape wheel and pinion a wheel of 96 teeth, 4 arms, meshes with the fly pinion of 6 leaves.

Beats per hour: 14,400

Stop work:

A brass pinion of 6 leaves on the arbor driving another of 8 leaves.

Winding work:

A steel winding wheel of 25 teeth meshes with two brass wheels, one on each barrel arbor, of 50 teeth each.

Motion work: Driven by a pinion of 12 leaves on the third arbor, making one turn in 6 minutes. This drives a wheel of 120 teeth on the right-hand side of the dial. This wheel has a coarse pitch wheel of 33 teeth mounted friction tight on its arbor, and carrying the minute hand. The wheel of 33 meshes with another similar on the squared hand-arbor. The hand-set arbor is integral with a pinion of 10 leaves meshing with another wheel of 120 teeth carrying the hour hand.

During normal running all these wheels turn together, for hand setting they all turn except the wheel of 120 meshing with the driving pinion of 12 leaves on the third going train arbor.

Thermometer: The sensitive element is a semicircular bimetallic strip made of steel and a whitish grey metal. The free end of the bimetallic strip carries a light pawl to index a wheel of 40 teeth each time the temperature cycle goes above a certain predetermined value.

Twist indicator: A privoted crossbar at the top has two weights, one at each end, and a spiral return spring. It carries a broken piece and a wire replacement to index a wheel of 40 teeth if the machine is given a twist as in starting.

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of this chronometer from Bennett in 1953. He mentions a letter from the firm of Breguet in 1953 giving the date of manufacture as 1821. In this letter M. G. Brown states that the record of sale of the chronometer was not entered in their old sales book and that as a result a Certificate of Origin could not be issued. Presented by Mr Gilbert Edgar C.B.E. in 1958. (reg. no. CAI-2121).

Exhibited: 'Pendulum to Atom', under the auspices of The Worshipful Company of Clockmakers at Goldsmiths' Hali, London, October, 1958; Musée International d'Horlogerie, La Chaux-de-Fonds, Switzerland May–September 1976, see exhibition catalogue, pp. 42, 53.

Bibliography: Daniels, 1975, pp. 87, 171; Bertele 1981, pp. 158, 159, 160; Gay Lussac and L. J. Arago, *Chronometres de Breguet*, 1819.

168 GIBBONS (probably John), English
c. 1818

MARINE CHRONOMETER *Plate 132*

Signature: On the dial only 'Gibbons's Patent Remontoire'.

Box: The movement protected by a brass drum fitting with a bayonet catch on a reduced diameter at the back of the dial plate. An outer brass canister-shaped bowl is pivoted in gimbals, it has a bezel with curved glass. There is a lock for the bowl and gimbal ring, the latter pivoting on the turned ends of brass screws in plates in the outside of the box. The winding key was fitted in a skew hole drilled in a corner of the box opposite the gimbal lock.

The brass-bound mahogany box is fitted with handles, a glazed top with hinged lid and catch, a lock, and the top edge of the bottom is rebated on the inside for a strip of thick velvet to exclude dust. Box 164 mm square, h. 164 mm.

Dial and hands: Engraved silvered brass dial, the engraving filled with black wax, subsidiary seconds dial. The dial is held in a recess in the dial plate by three screws on the inside of the ring of hour numerals.

Blued steel hands.

Movement

Dial plate diam. 89·1 mm; front plate diam. 64·4 mm; back plate diam. 64·4 mm; frame h. 23·9 mm.

Frame: Full plate construction with a detachable barrel bridge, and four turned pillars, the back plate retained by large blued steel screws. The back plate is cut away for the escape wheel and impulse roller planted level with the plate. The front plate fits in a turned recess in the dial plate, there is a positioning peg and three eccentric-headed blued steel retaining screws. The centre of the dial plate is turned away to leave room for the under dial work.

Fusee: Fitted with the usual stop-work and maintaining power, and with the setting-up-work on the barrel bridge. The maintaining detent is returned by a piece of blued steel wire pointing down from the back plate since the remontoire is planted in the space occupied by a normal return spring. A brass dust-excluding tube is carried on the winding square. The mainspring, apparently original but with new outer hooking, is signed 'Rich^{d} Smith, No. 5 Queen Street, Clerkenwell London, June 26th 1818'.

Going train: The usual layout and construction, the brass wheels gilded, the steel pinions and arbors well finished and polished.

Jewelling: The pivots of the fourth and all the escapement and remontoire arbors in pierced jewels, those of the escapement and remontoire where possible with endstones. A diamond endstone in a blued steel ring in the balance cock.

Escapement: A development of Earnshaw's spring detent escapement. The brass escape wheel gilded and not sunk out. The steel impulse roller of comparatively large diameter, sunk out on its underside and not jewelled. The polished impulse face is radial, the edge of the roller is also polished. The straight detent, now damaged, is screwed to the bottom and follows the edge of a gilded plate screwed and pinned to the underside of the back plate. The locking stone is triangular, the passing spring gold, riveted to the side of the detent.

Balance: Bimetallic two-armed balance of Earnshaw type, with small brass segment weights held by screws on the inside, and with brass timing nuts on the ends of the arms. The balance is held by two screws on a brass collet on the staff. Diam. of rim 27·1 mm, h. 2·9 mm.

Balance spring: Blued steel helical spring of 9 turns, with terminal curves, pinned to a solid brass collet, and with the upper terminal clamped by a plate and screw on the edge of a steel stud on the balance cock. The upper terminal is very short and the spring is fixed almost at the circumference.

Remontoire or constant force device: Such a device worked on the following principle: a helical spring colleted on the escape wheel arbor provides the torque to impulse the balance each time the escapement is unlocked. Towards the completion of impulse the escape wheel unlocks another similar coaxial wheel and causes the remontoire spring to be rewound by the train. The escapement is thus isolated from the train except during the moment of unlocking.

The escape wheel arbor is pivoted at its upper end in a cock on the back plate. At its lower end it carries a pierced jewel in a hollow brass setting with the flat end of the arbor acting as an endplate. Below the escape wheel and arbor is the rewinding escape wheel, also of gilded brass, and similar to the upper one. It is mounted on the escape pinion and pivots in the frame below and a cock above. The upper pivot extends through the pierced jewel in the cock and passes into the jewel on the end of the escape wheel arbor. The two escape wheels are thus coaxial but can turn independently of each other.

The blued steel helical remontoire spring, of some 13 turns, with terminal curves is pinned at its upper end to a brass collet immediately below the escape wheel. At its lower end it is clamped to the long extended upper pivot of the escape pinion.

The lower escape wheel is locked on a spring detent. There was probably originally a locking stone but this has been replaced by a piece of round wire. Unlocking is achieved by a jewelled detent, the jewel acting on the extended end of the locking detent. An arbor pivoted in cocks in the frame carries the unlocking detent at its lower end and an arm in the path of the upper escape wheel teeth at its upper end.

Safety device: It is important to prevent the lower escape wheel from being unlocked at the wrong moment and over-tensioning the remontoire spring. Alternatively, if the driving torque fails in the train, the remontoire spring could run right down. These two possibilities are prevented by an extra device. The steel frame clamped to the extended upper pivot of the lower escape arbor carries on an arm two pins separated by slightly less than the space of an escape wheel tooth. Fixed to the brass jewel setting on the upper escape wheel arbor is a long tapered arm passing between the pins carried on the lower arbor.

During normal running the pins and arm follow each other round without touching. If, however, the lower wheel is inadvertently unlocked, for example by an external shock, one of the pins on the steel arm at once catches up the brass arm and the lower wheel is held. When the escapement is unlocked the brass arm moves forward with the upper escape wheel, and since this re-unlocks the lower wheel normal conditions cannot be re-established, because the pin on the steel arm continually catches up the brass arm. So an external agency is needed to correct matters. This is provided by a pivoted lever system with return springs operated manually on the edge of the dial plate. On pressing a projection on the edge of the dial plate between the 5 o'clock and 6 o'clock divisions, the detent for the lower escape wheel is held out so that this can catch up its correct position relative to the upper one. One would presumably do this as a matter of course whenever the chronometer was wound, but this would involve unscrewing the bezel.

In the event of driving torque failure, the brass arm overtakes a pin on the steel arm and the escapement cannot advance until sufficient torque reaches the lower escape arbor to overcome that of the remontoire spring. Although very ingenious, this device was doomed to failure, because of its unreliability and complication.

Going-train counts:
Great wheel (fusee) 64 teeth, 7 turns of groove
Centre pinion 14 leaves, wheel 90 teeth, no crossings
Third pinion 12 leaves, wheel 80 teeth, 6 arms
Fourth pinion 10 leaves, wheel 82 teeth, 6 arms
Escape pinion 8 leaves, wheel 12 teeth, 4 arms
Beats per hour: 14,760

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves
Hour wheel 60 teeth, minute wheel 64 teeth

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of this chronometer in 1936 from Malcolm Gardner. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1932).

Note: A patent, No. 4214, taken out on 29 January 1818 by George Prior, describes a remontoire working on exactly the same principle as that fitted in this chronometer. There is apparently no patent taken out in the name of Gibbons so it is assumed that George Prior took it out for him.

Bibliography: Bertele 1981, p. 191.

169 LEGO

c. 1818

MARINE CHRONOMETER *Plates 133a–f, 134a–b*

Signature: On the dial 'No 15 Inventé et fait par Lego à Lorient'.[1]

Box: The movement contained in a grained and lacquered brass canister, the bottom weighted with a disc of brass, offset, and a levelling weight of lead, and fitted with a bayonet catch in the bottom. The knurled flat glazed bezel fitting friction tight on the outside of the edge of the drum. The glass is drilled for winding through the dial. The canister is gimballed in a well-made wooden box. There is no provision for locking the gimbal ring and the key once fitting in a slot in the right-hand side panels of the box is missing. There is the usual lock, and a sliding panel in the top over a circular aperture. There are no carrying handles. Box base 158 mm square, h. 133·5 mm.

Dial and hands: Flat enamel dial with subsidiary indications of hours and minutes and seconds, and with a hole for the squared winding-arbor, the dial with hair cracks. There are two rectangular-section dial feet with their ends passing into slots in the front plate, the dial is held by screws through the sides of the feet into brackets on the front plate. There is no dial plate. The back of the dial signed in the enamel 'Lucard'.[2] (See cat. nos 10, 11, 120, 121.)

Blued steel moon hands.

Movement

Front plate diam. 76·5 mm; back plate diam. 71·2 mm; frame h. 18·0 mm; frame h. over the barrel bridge 30·9 mm.

Frame: Built up on the front plate, two long turned pillars carry a bridge over the barrel. The going train arbors are pivoted in the front plate and in a detachable crescent-shaped bridge carried on three short turned pillars. The complete escapement and balance assembly is also planted on both sides of the crescent-shaped bridge.

Going barrel: Very large compared with size of balance, wound through the dial, with the ratchet and click on the dial side of the front plate. The well-made mainspring hooked with an eye to a steel hook in the brass unsnailed boss of the arbor. The outer end solid hooked to a slot in the barrel wall. The mainspring signed 'Vincent Mai 1818 20 Francs'. There is a five-turn stop-work on the end of the barrel.

Going train: The offset centre arbor drives the train in the usual way. The centre wheel meshes with a brass pinion driving a wheel turning once per hour and with the cannon pinion on its arbor. The pinions and arbors are well finished and polished, the brass wheels circular grained. The lower pivots of the third and fourth arbor are supported on steel friction rollers.

Jewelling: All the pivots in the escapement run in pierced jewels except the detent locking the escape wheel. The balance bearings have endstones, a diamond in the balance bridge. The pivoted remontoire detent pivots have steel endplates.

Escapement: A type of constant force escapement in which impulse to the balance is given by a helical spring via a pivoted impulse detent. The helical spring is then rewound by the escape wheel. This occurs at each alternate swing of the balance. The impulse detent is released at the correct moment so as to impulse correctly. A pivoted jewelled roller, carried on an arm on the impulse detent arbor, lands on a polished steel pallet on the balance staff to give this impulse. The impulse detent arbor carries a second smaller pivoted roller which releases the escape wheel via another pivoted detent at the end of impulse, so that the impulse detent can be rewound. This whole complicated system is most beautifully and carefully made and shows evidence of the greatest care, resource and skill in its construction. There is provision for altering the set up of the helical impulsing spring so as to adjust the amount of impulse, its fixed end is connected to an arm like an index, with a pointer moving over a scale.

The principle of the mechanism is similar to that of Breguet as fitted in his No. 428, cat. no. 167, except that the escape wheel teeth are locked directly on a detent. In Breguet's mechanism the locking force is demultiplied by a wheel and fly, the latter being locked on a detent.

Balance: Bimetallic four-armed balance with brass compensation weights closely resembling that of Louis Berthoud as fitted in his No. 127, cat. no. 13. There are even tapped holes in the ends of the brass weights towards the free ends of the rim but no screws have been fitted. Note also the similar balance bridge with its bearing, and the balance spring stud. Diam. of rim 23·9 mm, h. 1·7 mm.

Balance spring: Blued steel helical spring of 10½ turns clamped concentrically to both collet and stud, without terminal curves. The steel stud has three levelling screws and closely resembles that used by Louis Berthoud.

Going-train counts:
Great wheel (barrel) 84 teeth, 5 turn stop work
Offset centre pinion 12 leaves, wheel 80 teeth, 4 arms
Third pinion 10 leaves, wheel 75 teeth, 4 arms
Fourth pinion 10 leaves, wheel 100 teeth, 4 arms
Escape pinion 10 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

A brass pinion of 30 leaves meshes with the centre wheel, and drives a wheel of 80 teeth, 4 arms, turning once per hour and carrying the motion work.

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute pinion 36 teeth

Provenance: Ilbert Collection; purchased from Clowes by Ilbert in 1939. Presented by Mr. Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1930).

Notes

1. There is a port called Lorient on the coast of France, south of Brest on the Bay of Biscay. There is also a village in Switzerland called L'Orient in the Vallée de Joux, Canton of Vaud, an area that became famous for repeating and complicated watch manufacture in the nineteenth century.
2. Lucard is given in Tardy 1971 as Place de Thionville, 1806–1820.

Bibliography: Bertele 1981, pp. 182, 183.

170 ULRICH AND CO

c. 1828

MARINE CHRONOMETER *Plates 134c–f, 135a–b*

Signature: Engraved on the plate in which the dials are set 'ULRICH & C^o^ No. 27 Cornhill LONDON N^o^ 2. By his MAJESTY'S Royal letters PATENT. Improved by EDWARDS AND HUNTER 43 Cornhill.' The engraving is filled with black wax.

Box: The movement contained in a deep brass canister, made from a sheet of strip brass bent and with a soldered butt seam, the bezel and bottom are soldered on. The dial plate rests in a turned rebate with the movement suspended from it. There was once a threaded bezel, but this now missing. There are four tapped holes in the bottom and several filled holes in the side of the canister, probably for some sort of gimbal suspension and levelling weight, all now missing. Diam. 181 mm, h. 185 mm.

Dial and hands: A subsidiary dial for hours, minutes and reserve of going, another for seconds. Both dials of silvered engraved brass, the engraving filled with black wax, held by screws to the dial plate. In the upper dial the coat of arms of George IV, raised and held with three screws, probably made of gold. Each dial is protected by a brass bezel with knurled edge snapping into a turned sink in the dial plate, and with a raised glass. The short square near the edge of the dial plate is for winding.

Blued steel hands.

Movement

On the inside of the back plate, under the fourth wheel driving the seconds hand the punched ébauche marks I over I.W. The front plate is similarly marked by the foot of the maintaining detent cock.

Dial plate diam. 170 mm; front plate diam. 153 mm; back plate diam. 153 mm; frame h. 107·5 mm, excluding added plate 3·0 mm th. on which the escapement is mounted

Frame: Full plate construction of the most massive proportions, with four balluster turned pillars, the back plate retained by two screws into the flanged end of each pillar. The end of each pillar is reduced and passes into a positioning hole in the back plate. Each of the plates is about 3·2 mm ($\frac{1}{8}$in) thick, the dial plate slightly less. This is secured by four short turned feet passing into holes in the front plate and screws set in the edge of the front plate. Covering the original back plate and secured by two steady pins and three screws is a brass disc of the same diameter and thickness. On it are planted the escape arbor, the detent and two steel pillars to carry the balance bridge. On the underside is scratched 'This Back Plate,'Scaped and Sprung & c by Simson ay 1838'. The name is partly erased by file marks. There are several filled and unfilled holes in the back plate and it seems likely that the chronometer was originally fitted with one of Ulrich's constant force escapements. There are also several carefully filled holes in the front plate and in the plate carrying the escapement.

Fusee: Very coarse pitch brass reversed fusee with a modified English stop-work. The maintaining ratchet wheel is steel and cut with a large number of exceedingly fine teeth. There are two maintaining detents pivoted in a cock on the front plate and the front plate itself. Each is returned by a spiral spring round its arbor and has a double nose acting on the ratchet wheel, and each acts half a tooth pitched before or after the other. The fusee groove is marked by the pressure of the exceedingly large chain.

The mainspring barrel opens with a snap-on cover at both ends. There are two mainsprings of very great strength separated by a brass disc in the middle of the barrel. One at least has been rehooked by hook and eye to the barrel wall. Each spring has a bride to hold the last coil against the barrel wall. The arbor is a composite of steel and brass, unsnailed, with the two hooks and squared at both ends. One brass setting-up ratchet and click is fitted on the dial side of the front plate, the other inside the back plate. The squared part of the arbor has a short extension under the dial for setting up.

The fusee is wound by a large brass wheel squared to the end of its arbor under the dial plate, in permanent mesh with a large brass pinion pivoted in the dial plate and the front plate and with an extended square beyond the dial.

Going train: The fusee and offset centre arbor are pivoted in the frame. The third and fourth wheels are pivoted between a potance on the back plate and the back plate itself. There is an additional wheel pivoted like the third and fourth wheels, meshing with a large pinion on the escape pinion arbor, and carrying a long arbor on an extended lower pivot. This arbor is pivoted in the dial plate and carries the seconds hand. The difference in style, thickness and colour of the brass of the centre, third and fourth wheels when compared with the wheel driving the seconds hand, and the style and finish of the pinions suggest that the centre wheel and the third and fourth wheels and pinions may all be later replacements. The present centre wheel is held by three screws on its collet which also has three filled holes, and is considerably thicker than the height of the collet boss positioning it. This suggests that the original train wheels were too thin to withstand the very great driving force and may have started to buckle. The third and fourth arbors also appear to have been replanted.

Jewelling: Only the pivots of the escapement arbors run in pierced jewels with endstones. A diamond endstone set in a blued steel ring is fitted on the balance bridge. The end of the seconds indicating arbor pivot in the back plate rests on a brass plug held by two screws in a sink in the plate like an endstone jewel setting.

Escapement: As now fitted it is a development of Earnshaw's escapement. The brass escape wheel is probably a later substitution after the alterations in 1838. It is not crossed out and only one screw is fitted to hold it on its collet. The collet is drilled and tapped for two screws, the wheel drilled for only one. The steel impulse roller is not jewelled, the radial impulse plane is slightly convex and polished as are the edge and bottom. There are three poising holes. The polished steel discharge roller, without an adjusting flat, is fitted with a narrow slip of steel instead of a jewel. The detent has apparently been broken and repaired. The foot is separate from the rest of the detent and uses only one of two steady pin holes. The spring part of the detent is clamped under a steel plate with a screw. The locking stone is triangular and the passing spring steel held under a screw head, and banking is provided for the detent pipe against a strip of brass with radiused end secured by a single screw.

Balance: A straight bimetallic crossbar formed by strips of brass and steel apparently soldered together. Straight brass rods stand on the ends on the steel side each carrying two adjustable weights and a brass screw. The brass screws are for mean time adjustments, the weights for altering the amounts of compensation by moving them up or down on the brass rods. The crossbar is held by screws on a brass collet.

This balance is similar to William Hardy's, cat. no. 73, except that in the latter the steel and brass are not soldered or fused together but attached by rivets near their ends. John Roger

Arnold took out a patent, No. 4531, in 1821 for a balance very similar to the one fitted on this chronometer, but in his the brass and steel are fused together. Diam. 67·1 mm, h. 45·4 mm.

Balance spring: Slightly conical steel spring of three full turns, faintly blued on the inside, grained white on the outside, without an overcoil or terminal curve. The inner end of the spring is pinned with a brass wedge in a rectangular hole in the brass collet. The collet is fitted on the reduced end of the boss to which the balance is screwed and held by a clamping screw. The outer end of the spring is clamped in a rectangular hole in a brass block with another piece of spring similarly clamped in a separate brass stud screwed to a steel bracket on the escapement plate. Both the brass block and stud are provided with a second rectangular hole and means for clamping a second short piece of spring concentric with and outside the first. The whole system constitutes a resilient stud and was presumably to perform the same function, namely, to cause the outer coil of the balance spring to breathe concentrically with the balance staff, and to prevent lateral pressures on the pivots and spring upsetting the latter's isochronal properties.

Going-train counts:
Great wheel (fusee) 112 teeth, 8 turns of groove (32 hours going)
Centre pinion 28 leaves, wheel 128 teeth, 6 arms
Third pinion 16 leaves, wheel 120 teeth, 6 arms
Fourth pinion 16 leaves, wheel 128 teeth, 6 arms
Escape pinion 16 leaves, wheel 15 teeth, no crossings
Beats per hour: 14,400

Additional fourth wheel 120 teeth, 5 arms meshes with a pinion of 15 leaves on the escape pinion arbor.

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves, brass
Hour wheel 60 teeth, minute wheel 64 teeth

Winding wheels:
Brass winding pinion 16 leaves
Brass winding wheel 45 teeth
Star wheel for reserve of going 24 teeth.

Provenance: Ilbert Collection, presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1943).

Exhibited: Pendulum to Atom under the auspices of The Worshipful Company of Clockmakers at Goldsmiths' Hall, London, October 1958.

Note: Johann Gottlieb Ulrich (1795–1875) formed a company with Joseph Croucher, who put up the money, to make very large chronometers to his design. The venture appears to have lasted from 1828–1832, and Croucher suffered heavy losses. Ulrich claimed to have discovered the middle temperature error of compensation in 1814, and subsequently expended a great deal of effort and research into designing a balance to eliminate it. The constant force escapement which he developed is probably the most complicated ever devised and was very expensive to make. He also worked on the problem of eliminating the effects of magnetism on the balance. (Some of these inventions are described in Gould 1923, pp. 142–3 and 193–5.)

Ulrich took out a number of patents:

No. 5136 on 26 March 1825, for a constant force escapement with a number of safety devices.

No. 5639 on 19 April 1828, for improvements to 'the remontoir detached escapement, and additions to the same' described in No. 5136.

No. 6064 on 22 January 1831, for 'certain improvements in chronometers'.

No. 7350 on 22 April 1837, for 'a device to prevent a chronometer balance from being brought to rest by a shock or circular motion of the instrument in the plane of the balance, the device or devices consisting of a novel construction of detents' and also for a means of compensation for the balance spring by a non-magnetic balance, and a method of adjusting the compensation of an astronomical timekeeper; a means of stopping the hands or presumably setting to time without upsetting a chronometer; a new method of discharging a striking train incorporated in a chronometer; a new method of discharging an alarm or warning watch incorporated into a chronometer; prevention of oxidation of the springs (presumably balance springs) of chronometers by covering them with a thin coat of some metal.

Related works: A complete and working example of a similar chronometer to cat. no. 170 is preserved in the Collection of the Worshipful Company of Clockmakers at the Guildhall, London. The chronometer is signed 'Joseph Croucher'.

Another, which is anonymous but numbered 10482, is in the Conservatoire Des Arts et Metiers, Paris, no. 1395. Its unusual compensation balance is also illustrated in the horological catalogue of the collection published in 1949, pp. 149 and 250.

Bibliography: Bertele 1981, p. 213; Cecil Clutton and George Daniels, *Clocks and Watches in the Collection of the Worshipful Company of Clockmakers*, London, 1975, p. 103.

171 JOSEPH BANISTER (1778–1875)

c. 1835

MARINE CHRONOMETER *Plate 135c–f*

Signature: On the dial only 'Banister Colchester. Patent No. 1'.

Box: The movement contained in a brass drum with a threaded bezel having a flat glass. This is a standard drum for a two-day chronometer, the holes for the gimbal mounting screws have been filled and there is the usual spring-loaded escutcheon plate in a turned recess in the base. The drum is provided with a fitted red leather travelling box with an arched top opening in two halves and with a catch and lock, the inside lined with pale yellow velvet. The drum can be positioned so that the dial is vertical behind a removable glass. There is a space at the back for the plain key. Box w. 148 mm, d. 96 mm, h. 160 mm.

Dials and hands: Silvered, engraved bras dial, the engraving filled with black wax, with subsidiary seconds and reserve of going indications. The dial plate is recessed to take the dial flush with the edge, there is a positioning peg and the dial is held by two countersunk screws.

Gold minute and hour hands, blued steel seconds and reserve of going hands.

Movement
Ebauche marks punched on the dial side of the front plate 'J.M.' Numbered under the maintaining detent 5000, and on the front plate inside 500.

Dial plate diam. 95·1 mm; front plate diam. 81·8 mm; back plate diam. 80·9 mm; frame h. 21·9 mm.

Frame: Full plate construction, the plates hand spotted, a detachable barrel bridge and four turned pillars, the back plate retained by blued steel screws. The dial plate, a thick ring of brass into which the movement fits in a turned recess, is held by three large brass dog screws with their heads partly filed away. A positioning peg is fitted in the dial plate with a corresponding groove in the front plate. The escape pinion arbor is carried through the back plate and pivoted in a cock, the back plate being sunk out for the escapement. A special balance potance has been fitted carrying the lower bearings of both the balance and impulse arm staffs, this potance has a moulded edge to the foot. A red brass dust-excluding pipe is fitted over the winding arbor and screwed and pinned to the back plate. The cock in two parts screwed together and steady pinned.

Fusee: Fitted with the usual stop-work and maintaining power, the setting-up-work on the barrel bridge with a return spring for the click. The barrel arbor is solid and not snailed, the mainspring unsigned, and hooked on a peg in the barrel wall. There are no marks or indications on the fusee assembly. Double clicks are fitted on the maintaining ratchet plate to work with the winding ratchet.

Going train: A well-made train of standard design, the brass wheels riveted to their polished pinions having polished arbors and pivots.

Jewelling: Only the pivots of the escape pinion arbor, the impulse arm staff and the balance staff in pierced jewels with endstones. A diamond endstone set in a blued steel ring is fitted in the balance cock.

Escapement: A type of constant force escapement in which a spiral spring gives impulse to a roller on the balance staff via a pivoted lever. Impulse is given in one direction only. The brass pivoted lever is provided with three arms. One is locked by a detent with passing spring, this being released by a normal jewelled discharge roller on the balance at an appropriate moment so that impulse can be transmitted by the second arm. The third arm is rewound by the short upstanding teeth of a duplex escape wheel. The long locking teeth of the escape wheel rest on the arbor of the pivoted lever. This is slotted to release the escape wheel at the end of transmission of impulse to the balance. The lever arm rewound by the escape wheel is faced with a polished steel plate.

The detent is of conventional dovetail design and fitted on a gilded brass block having an arm into which the banking screw is threaded. Adjustment of the detent towards or away from the balance is made by a screw with an offset peg in the end of the threaded portion against which the end of the foot rests. The locking stone is of triangular section, the passing spring of gold held under the head of a screw.

There are a number of unfilled holes in the balance cock whose overhanging table is separate and secured by screws and steady pins to the vertical part of the foot. It appears from the comparatively crude workmanship of the escapement parts, especially the two cocks, that a standard chronometer movement was modified and fitted with these extra parts by Joseph Banister, a clock and watchmaker.

Balance: Bimetallic two-armed balance with cylindrical compensation weights held by screws from the inside and two pairs of brass timing screws. Two screws secure the balance to a brass collet on the staff. Diam. of rim 25·5 mm, h. 2·8 mm.

Balance spring: Blued steel helical spring of 10 turns, with terminal curves, pinned to a brass stud and slotted brass collet.

Going-train counts:
Great wheel (fusee) 90 teeth
Centre pinion 14 leaves, wheel 90 teeth, 5 arms
Third pinion 12 leaves, wheel 80 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 3 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 14 leaves, minute pinion 18 leaves
Hour wheel 56 teeth, minute wheel 54 teeth

Up-and-down indicator: A pinion of 12 leaves on the fusee arbor meshes with a wheel of 120 teeth carrying the indicating hand.

Provenance: Ilbert Collection; in his inventory Ilbert records that he purchased this chronometer from Bennet in 1948. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1949).

Note: Joseph Banister (1778–1875) of Colchester obtained a patent, No. 7083, on 7 May 1836, covering a type of gravity escapement for a precision regulator clock and a similar improvement applicable to watches and chronometers. A description of the clock escapement and a good deal of biographical information about Joseph Banister is given in Bernard Mason, *Clock and Watchmaking in Colchester*, 1969. It is not clear what the improvement to watches and chronometers referred to in the patent actually is, but it is assumed that this chronometer is an example.

Bibliography: Bertele 1981, p. 208.

172 EUGENIO COUILLAUT

c. 1870

MARINE CHRONOMETER *Plate 136a–d*

Signature: On the dial 'Eugenio Couillaut No. 3 Brevete (Patented) MADRID'.[1]

Box: The movement contained in a brass bowl of English pattern, with a threaded bezel and flat glass, the brass circular, grained and lacquered. In the base is a circular escutcheon plate of large diameter with an eccentric winding hole once fitted with a return spring. The bowl is gimballed in the French way to brass brackets in the side of the box. There is a gimbal lock of French pattern. The ebony box has a tipsy key specially made to wind the going barrel. This key rests in a corner gusset. There is provision for another, now missing, in the right-hand side panel between the top and the lid, accessible when the lid is opened. There is also a box lock and carying handles and a rectangular ivory plate attached to the front of the top. There is no provision for excluding dust in the join between the top and the bottom. Box base 176 mm square, h. 176 mm.

Dial and hands: Engraved silvered brass dial, the engraving filled with black wax, fixed with three screws on the edge to the dial plate of the same diameter.

Gold hands including the seconds. No reserve of going indication.

Movement

Dial plate diam. 106·2 mm; front plate diam. 84·0 mm; back plate diam. 84·0 mm; frame h. 31·0 mm.

Frame: Full plate construction with a detachable barrel bridge and four turned brass pillars each having a central steel shaft with a threaded portion at both ends. The front plate is secured by brass nuts and washers, the back plate by steel nuts and washers. The whole construction is remarkably solid, the brass parts are finished with a fine grain. The dial plate consisting of a disc with circular central aperture is fixed to the front plate by three short turned feet and screws in the edge of the front plate.

Going barrel: Fitted with a five-turn stop-work flush on the great wheel end. The arbor has an unsnailed brass boss, the spring is hooked with an eye at both ends, it is probably original but has been considerably shortened and so has lost any signature it may have had. The temper is very uneven.

Going train: Heavy construction, the wheels remarkably thick but well finished and grained, the pinions of comparatively low numbers, well finished and polished, but with unusually large diameter pivots. The fourth and escape wheels are fixed with screws to brass collets.

Jewelling: The fourth arbor pivots in pierced jewels, those of the escapement in pierced jewels with endstones, a diamond endstone set in a steel ring in the balance cock. The jewelling is of English type, set in brass rings in sinks in the brass frame parts, but the retaining screws are not fitted flush.

Escapement: A constant force mechanism in which the going train is used to rewind a spiral spring attached to a brass wheel with four teeth. This wheel is normally held locked by an ordinary detent in compression, unlocked by a discharge roller on the balance staff. Impulse is transmitted to the balance by a brass tooth on the four-armed wheel contacting a radial jewel on the steel impulse roller on the balance staff. At the end of impulse a jewelled tooth on the four-toothed wheel trips a detent in tension holding up a normal fifteen-toothed brass escape wheel. An escape wheel tooth picks up a second jewelled tooth on the four-toothed wheel and rewinds the spiral spring whilst resetting the latter wheel. This type of mechanism gives good results if carefully used and not subjected to external disturbances. However an external shock can easily cause the detent locking the four-armed wheel to release it at the wrong time. At best this will cause the machine to advance by one escape tooth, but it could so happen that rewinding is in progress when the balance is in the unlocking position. The escapement could then be seriously damaged.

A numbered of adjustments are incorporated, including bankings for the detent locking the normal escape wheel.

Balance: Bimetallic two-armed balance, the steel part of the rim blued, fitted with cylindrical brass compensation weights and brass timing screws in the rim at the ends of the arms. It is held by two screws on a brass collet on the balance staff. Diam. of rim 28·5 mm, h. 3·4 mm.

Balance spring: Blued steel helical spring of $11\frac{3}{4}$ turns, with terminal curves, pinned to a split brass collet with poising tail, and to a brass diamond-shaped stud on the balance cock.

Going-train counts:
Great wheel (going barrel) 104 teeth, 5 turns stop-work
Centre pinion 10 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth 5 arms
Escape pinion 10 leaves, wheel 15 teeth, 5 arms
Beats per hour: 14,400

Motion work:
Cannon pinion 18 leaves, minute pinion 14 leaves
Hour wheel 56 teeth, minute wheel 54 teeth

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of this chronometer from Malcolm Gardner in 1933. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1959).

Note

1. Eugenio Couillant is not recorded in Baillie 1951, but Tardy 1971 mentions a Couillant as having taken out a patent in 1868 for an escapement and a system of compensation.

Bibliography: Bertele 1981, p. 217.

173 MAKER UNKNOWN

Probably late 19th century[1]

MARINE CHRONOMETER *Plate 137a–d*

Box: Two brackets on the dial plate carry pivots by which the movement is suspended in a gimbal ring in a plain mahogany box. A canister fitting over the movement was once attached to the dial plate, and a glazed ring attached with a bayonet catch over the dial, but these are both missing.

The box is fitted with a front lock, a catch for the gimbal ring and has a glazed panel in the top under a hinged lid with catch. The side panels are warped and the joints splitting. Box 178 mm square, h. 173 mm.

Dial and hands: Flat silvered engraved brass dial, the engraving filled with black wax, secured by three turned feet and pins to the front plate.

The hands missing.

Movement

Dial ring diam. 138 mm; dial diam. 126·6 mm; front plate diam. 111·8 mm; back plate diam. 112·3 mm; frame h. 32·8 mm.

Frame: Full plate construction with three turned pillars riveted to the back plate. The front plate retained by pins. The escapement mounted on a separate section on the back plate, held by two screws and steady pins. The brass parts straight grained and lacquered. There are various carefully filled holes in the plates. The dial ring is secured to the dial by two screws.

Going barrel: With click-work on the dial side of the front plate. There is no provision for stop-work. The mainspring, of very inferior quality but apparently original, is hooked with an eye at both ends. The barrel arbor has an unsnailed brass boss. The brass return spring for the winding click is of unusual shape and works almost without sliding on the click.

Going train: Strongly made but poorly finished to clockmaking rather than chronometer standard.

Jewelling: Only the balance staff pivots in pierced jewels with endstones. The pierced jewels are inverted train jewels with the flat side towards the endstone.

Escapement: An ingenious remontoire escapement designed originally by John de Lafons[2] in which impulse is given to a steel pallet on the balance staff by a combined spring and arm. A seven-toothed escape wheel is normally held locked by a pallet system whose only purpose is to lock the teeth. A fork on the pallet frame works in conjunction with a table roller on the balance staff. The fork is poised and the locking surfaces of the pallets lie on arcs struck from the pallet centre.

Looking down from the back starting with the balance at the extreme of its clockwise rotation, the action is as follows. The escape wheel is locked on the entry pallet and the impulse arm is held with its spring portion in maximum tension. It has an inclined plane, the end of which rests on a brass pin on the escape wheel until the return of the balance anticlockwise. The jewel pin on the roller on the balance staff enters the fork notch and causes the fork and pallet assembly to turn clockwise. The escape wheel tooth held locked on the entry pallet is released and the wheel advances a small amount until another lands on the exit pallet when it is again locked. The small movement of the escape wheel causes the brass pin to move past the end of the inclined plane on the impulse arm. The impulse arm is thus released and moves towards the escape wheel. Its free end contacts the steel pallet on the balance staff giving impulse. The balance continues anticlockwise completely detached from the escapement. On its return clockwise the fork is moved over to the anticlockwise extreme and the escape wheel released. This then turns nearly a tooth space until another tooth is locked on the entry pallet. At the same time a brass pin contacts the inclined plane and rewinds the impulse arm.

This device combines simplicity with security of function. The balance assembly is highly detached from the escapement and impulse is constant except for the effects of temperature on the impulse arm spring. The unlocking friction is a variable depending on the driving torque at the escape wheel. The wheel and pallet action would probably function without oil, but the brass lifting pins and inclined plane would probably need to be oiled. The latter would not affect the transmission of energy to the balance.

Balance: Bimetallic two-armed balance, the bimetallic rim sections soft soldered to the ends of the arms. Brass segment weights are held by screws from the outside, and brass timing screws with steel threads in the rims at the ends of the arms. The rim sections are so thick that it seems unlikely that they could have functioned satisfactorily. The balance is riveted to a brass collet on the staff. Diam. of rim 28·3 mm, h. 2·2 mm.

Balance spring: Blued steel open coiled spiral spring, badly pulled out and damaged. It is impossible to say if there was originally a terminal curve.

Going-train counts:
Great wheel (barrel) 96 teeth
Centre pinion 12 leaves, wheel 64 teeth, 4 arms
Third pinion 8 leaves, wheel 60 teeth, 4 arms
Fourth pinion 8 leaves, wheel 96 teeth, 4 arms
Escape pinion 6 leaves, wheel 7 teeth, no crossings

Motion work:
Cannon pinion 10 leaves, brass, minute pinion 8 leaves, brass
Hour wheel 32 teeth, minute wheel 30 teeth

Provenance: Ilbert Collection; in his inventory notebook Ilbert records the acquisition of the chronometer from Lumsden on 14 June. The year is not stated but it was probably 1937 or 1938. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1926).

Notes

1. It is impossible to be certain of the date of manufacture or the country of origin of this machine. In view of the simplicity and ingenuity of this constant force escapement it is unfortunate that the balance and spring system prevented the chronometer giving a good performance.

2. John De Lafons (1793–1816) of 66, Threadneedle Street, London, won thirty guineas from the Society of Arts for this escapement in 1801. He also patented a marine alarm chronometer in 1805 (Patent no. 2893).

Bibliography: For details of De Lafon's escapement see Abraham Rees, *Rees's Clocks Watches and Chronometers*, London, 1819–20, pp. 12, 13, and Chamberlain 1941, pp. 195, 196 and 197.

III.ii

TRAIN REMONTOIRES

174 GEORGE MARGETTS

c. 1790

MARINE CHRONOMETER (8-DAY)
Plates 137e–f, 138a–c

Signature: On the dial only 'Margetts LONDON INV^{T} No 80'.[1]

Box: The movement contained in a brass drum. The glazed bezel fits on the outside of the drum and is fixed by two screws passing into threaded holes in the dial plate. It has a domed glass. The bottom is removable but held by two screws in the side. It has a glazed panel over the balance and winding hole with a cover plate. There was once provision for winding at the side of the drum but this has been removed and the hole in the drum filled by a brass piece attached to the bracket on the back plate in which the winding wheel was pivoted. Drum diam. 130 mm, h. 88 mm overall.

Dial and hands: Flat enamel dial, signed on the back in red in the enamel 'Weston', fitting flush in a recess in the dial plate and fixed by a central brass boss and a screwed fixing washer on the underside of the dial plate. The minute and seconds divisions do not appear to have scribed marks under the black enamel.

Blued steel hands, the seconds held on its flanged tube by a screw in the end of the tube.

Movement

Dial plate diam. 128·6 mm; front plate diam. 123·5 mm; back plate diam. 124·1 mm; frame h. 44·3 mm.

Frame: Full plate construction with four lightly made steel baluster pillars. The front plate is secured by pins and the back plate by screws and washers in the pillars. The balance is planted inside the frame between a bearing in the front plate and another in a potance screwed to the top of the back plate and passing down at the edge of a hole in the plate.

There are numerous empty holes in the plates and the movement appears to have undergone a good deal of modification. Apart from the removal of the side-winding there was probably a revolving agate disc driven by the great wheel, on which the end of the balance staff rested in the dial up position, the disc moistened with oil from a piece of leather. There appears also to have been a remontoire on the fourth arbor between the pinion and the wheel.

Fusee: Fitted with the usual stop-work and maintaining power, a toothed wheel is cut integrally with the larger end of the fusee to receive the drive from the side-winding wheel that was once fitted. The maintaining detent return spring is replaced by a piece of brass wire. A short squared arbor at the back for winding the fusee. The solid unsnailed barrel arbor with an extended square at that end only carrying the setting up ratchet. The winding ratchet works with two clicks and there are no marks or signature inside on the parts of the fusee assembly. The mainspring is a modern replacement punched A.M.F. and numbered 1322. There is no intermediate wheel, although the chronometer runs for eight days.

Going train: Lightly made and crossed out, centre and third wheels riveted to their pinions, the latter, their arbors and pivots polished.

Remains of the remontoire: The arbor of the fourth pinion is planted with one pivot in the back plate, the other extending through a hole in a potance screwed to the outside of the front plate. The end of the extended pivot is squared and carries a six-armed wheel with six square tooth-like extensions of the arms extending beyond the rim. The fourth wheel is mounted on a brass collet pivoted in the end of the squared arbor and in a cock on the front plate. The fourth wheel and pinion and the brass six-armed wheel are thus planted coaxially.

A spiral spring is colleted on the fourth wheel arbor, and its outer end is pinned in a stud on the six-armed wheel. Between the spring collet and the fourth wheel is a thin brass pinion. At present the drive reaching the fourth pinion causes it to turn until two pins in the six-armed wheel passing between the spokes in the fourth wheel carry this wheel round by its spokes. The spiral spring is merely held in tension and neither this nor the brass pinion has any function.

Jewelling: The pivots of the escape arbor and balance staff run in pierced jewels in brass settings, held by screws in suitable sinks in the frame. The lower escape arbor and balance pivots have endstones, that of the balance staff a diamond. The lower pivot of the fourth pinion arbor runs in a hole in a bush of silvery alloy and rests against an endstone. This assembly constructed as an ordinary jewel setting.

With the exception of the fusee arbor, pivoted in the frame, the train pivots run in fixed bushes of different alloys. The centre arbor rear pivot bushing is a grey-white alloy. This has an ordinary brass replacement bush set in it, as has the third arbor rear pivot bushing which was originally a dull copper-red alloy. The other train pivots run in bushes of the same copper-red alloy.

Escapement: A development of Earnshaw's spring detent escapement with unusual proportions. The brass escape wheel has twenty teeth, and the impulse roller is only slightly larger in radius than the radius to the tip of the discharge jewel. Both rollers are steel, dull polished and with their surfaces rounded. The impulse roller is jewelled radially and has a very large passing hollow.

The detent has apparently been broken where the spring joined the original foot, then resoldered to a replacement foot planted nearer the balance and to one side, thus putting the spring in greater tension. Locking is achieved against a steel face of the triangular-section block left integral with the detent. This face shows signs of wear. Banking is provided against the edge of the head of an eccentric screw. Both detent and banking are planted on the inside of the front plate. The gold passing spring is fixed under the head of a screw and lies parallel with but under the detent, the horn is formed with the end projecting down to meet it.

Balance: Bimetallic three-armed balance with brass weights held by screws, and steel timing screws set in the rim at the ends of the arms. It is attached to a brass collet on the staff by three screws through the central boss. The three arms appear to be disproportionately thick, extending to nearly half the height of the rim. Diam. of rim 28·0 mm, h. 1·72 mm.

Balance Spring: Blued steel helical spring of 6¼ turns with a very short terminal curve to the steel collet, and none to the stud where the end of the spring is clamped practically at full diameter under a steel plate. The brass stud is screwed and pinned to the edge of the balance cock.

Going-train counts:

Great wheel (fusee) 144 teeth, the fusee has about 16¼ turns of groove, and the winding wheel cut in the larger end has 72 teeth
Centre pinion 12 leaves, wheel 120 teeth, 6 arms
Third pinion 12 leaves, wheel 72 teeth, 6 arms
Fourth pinion 12 leaves, wheel 72 teeth, 6 arms
Escape pinion 12 leaves, wheel 20 teeth, 6 arms
Beats per hour: 14,400

All four going train pinions are the same size, the third and fourth wheels are the same size, and all the train wheels, including the great wheel, are cut with the same cutter producing the same rather shaky and uneven tooth form. The pitch used is thus the same throughout the train, about 0·38 module.

Motion work: also of the same pitch throughout, 0·38 module.

Cannon pinion 16 leaves, minute pinion 20 leaves
Hour wheel 60 teeth, minute wheel 64 teeth

Provenance: Ilbert Collection; Ilbert in his inventory notebook records the acquisition of this chronometer in 1936 from Jauncey. He also states that its earliest appearance in the ledger records of the Royal Observatory, Greenwich, is in 1821 when it was issued to HMS *Lever*. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1942).

Note

1. George Margetts was born on 17 June 1748 and died on 27 December 1804. He became free of the Clockmakers Company in 1779 and was elected to the livery in 1799. In 1788 he was declared bankrupt. A similar 8-day marine chronometer by G. Margetts, No. 102, without a remontoire, is in the Collection of the Worshipful Company of Clockmakers and is detailed in their Catalogue.

Bibliography: Further information about Margett's life and work is to be found in *AH*, March 1970, by George Daniels and vol. VII, September 1971, by A. J. Turner.

175 MAKER UNKNOWN, probably English
c. 1900

MARINE CHRONOMETER (8-DAY)
Plates 138d–f, 139a–d

Box: The movement contained in a lacquered bronzed brass canister, with a threaded bezel having a flat glass. Diam. overall 138 mm, h. 76 mm.

Dial and hands: Flat silvered brass dial secured by two screws to the dial plate. The figures are painted on, and the surface finished with a circular grain.

Crudely made blued steel hands, the minute hand with a square boss, the hour hand with a brass tube, the seconds hand riveted to a collet on its pipe.

Movement

Dial plate diam. 119·7 mm; front plate diam. 106·8 mm; back plate diam. 92·4 mm; frame h. overall 41·8 mm.

Frame: A type of half plate construction, with three turned pillars, the back plate retained by steel screws and washers. The back plate is in two layers, with a smaller diameter plate screwed and steady pinned on top of the main back plate. There is a rectangular sub plate on the front plate under the dial for three of the bearings on that side, and the motion work. The dial plate has a flange for the dial and is then reduced and tapered to fit almost flush with the edge of the front plate. It is secured by four screws through the front plate from the movement side, the centre is turned out, and it has been made deep to leave room for all the under dial work. The flanged edge rests in a turned sink in the canister to suspend the movement. The pillars are attached to the front plate by large steel screws.

Going barrel: Keywound through a hole in the dial, the barrel is fitted with five-turn stop-work on the cover end, the stop finger held with a screw. A screw in the barrel wall fits in a slot in the cover to prevent this from turning. There is a large square hole in the front plate filled with a piece of brass soldered in, for the lower barrel arbor bearing. The bearing in the back plate has been moved out. It seems likely that a larger barrel has been fitted than was at first allowed for. The great wheel is of a red colour and made probably of either phosphor bronze or beryllium copper in order to have greater strength.

Going train: A train remontoire is fitted on the third arbor so that in addition to the normal going train there are three more wheels and three more pinions, the last carrying a fly. The pinions are unpolished and the train is crudely made. All burrs have been removed but little attempt has been made to highly finish even the working surfaces.

Jewelling: The rear fourth arbor pivot and those of the escapement in pierced jewels, the balance staff with endstones, including a diamond endstone in the balance cock in a polished steel setting. The balance jewelling is of typical English style with brass settings held by screws. The remainder is of an inferior quality and finish.

Escapement: A development of Earnshaw's spring detent escapement. The teeth of the brass escape wheel well cut, with the rim and arms sunk out, the crossing out of the arms is most crudely done. The wheel is mounted on a brass collet on the arbor of the escape pinion. The steel impulse roller is poorly made and polished, but set with a well-made jewel, the impulse face leaning towards a radial to the tip. The discharge roller is also poorly made, and jewelled with a wedge-shaped jewel. The detent is screwed in a slot on the edge of a brass block having an extended arm carrying the banking screw. The well-made locking stone is of half-round section, and the passing spring of steel pinned in a block riveted to the detent which is particularly crudely made.

Balance: Bimetallic two-armed balance similar to Earnshaw's design, the steel parts blued, with brass segment weights fixed by screws on the inside. The poising screws at the free ends of the rims are brass, with steel timing screws at the fixed ends. The balance is riveted to a brass collet on the staff. Diam. of rim 22·4 mm, h. 1·9 mm.

Balance spring: Blued steel closely coiled helical spring of 9 turns, with terminal curves. The blued steel collet consists of a block in which the spring is pinned, joined by a narrow arm to another solid block adjusted on the staff. The blued steel stud is screwed to the edge of the balance cock in a shaped slot, there is a steady pin set in the cock.

Train remontoire: Two third wheels are fitted on the pinion arbor, one rigidly fixed on a brass collet on the arbor, the other mounted on a hollow steel arbor and free to turn on the pinion arbor. Apart from oiling there is no provision for reducing or stabilising the friction between these two arbors. A strong blued steel helical spring of about eight turns with short terminal curves is pinned to a block carried on the hollow arbor. The other end is pinned to an arm standing off a steel boss adjusted on the pinion arbor to retain the hollow arbor and clamped by a screw having four flats on its head. Connection between the two wheels is thus made by the helical remontoire spring.

The third wheel fixed to the pinion arbor drives the remontoire train, the other third wheel drives the normal fourth pinion and escapement in the usual way, and is impelled by the remontoire spring. Apart from the third wheel fixed to the pinion arbor, the remontoire train consists of two wheels and three pinions, the last wheel driving the third pinion with a fly on its arbor. The first of the wheels and pinions is similar to the fourth wheel and pinion, on its arbor are two arms at different heights one of which rests on the edge of one of two cylinders carried on the true fourth arbor. Each cylinder has a flat so that the arm resting on the edge is released approximately, every 30 seconds. The remontoire train is thus released and runs until the other arm touches the other cylinder and the helical spring is wound. The two arms and cylinders are carried on the dial side of the front plate, the pivot runs in a tiny jewel in a steel setting in the cock.

Safety device: To prevent the initial set up of the remontoire spring from running down in the event of failure to wind the mainspring or for any other reason, the third wheels are provided with a stop device so that they cannot turn relative to each other more than a small angle. This angle is slightly greater than their angular displacement each time the remontoire rewinds so that the stop is normally inoperative. The fixed third wheel has a slot on the inside of its rim and the third wheel a pin pointing down into the slot. There is also a brass block carried on the fixed third wheel with a screw pointing over the slot to vary its effective length. The free third wheel has ten steel pins set in its rim, but these have been cut off flush with the rim. They suggest that the wheel was once the pin wheel of a striking train, modified for its present purpose.

The pivots of the remontoire fly arbor each run in steel bushes. The rear bearing, which has a steel end plate, is set in a potance screwed to the inside of the front plate.

Going-train counts:
Great wheel (going barrel) 80 teeth, 5 turn stop-work
Intermediate pinion 12 leaves, wheel 60 teeth, no crossings
Centre pinion 10 leaves, wheel 72 teeth, 4 arms
Third pinion 12 leaves, wheel 70 teeth, 4 arms
Fourth pinion 7 leaves, wheel 56 teeth, 4 arms
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 14,400

The third wheel driving the remontoire train has 80 teeth driving a pinion of 8 leaves carrying the two-armed locking lever and a wheel of 51 teeth.

The rest of the remontoire train consists of a pinion of 12 leaves carrying a wheel of 56 teeth meshing with the fly pinion of 7 leaves. The wheel of 56 had a steel pin in the rim, now cut off flush with the rim and so was probably the warning wheel, perhaps from the same striking train as the free third wheel.

Motion work:
Cannon pinion 36 leaves (brass), minute pinion 7 leaves
Hour wheel 84 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1942. Presented by Mr Gilbert Edgar C.B.E. in 1958 (reg. no. CAI-1984).

IV

DEVICES INTENDED TO ELIMINATE THE VERTICAL POSITIONAL ERRORS

IV (cat. nos 176–193)

REVOLVING ESCAPEMENTS AND TOURBILLON AND KARRUSEL MECHANISMS

One of the problems that is most difficult to resolve with any watch worn on the person or frequently carried from place to place is the action of gravity on the balance and spring and on the escapement. If any part of the balance and spring system is not balanced exactly by a similar part elsewhere the system is said to be 'out of poise'. It is usual for considerable care to be taken in 'poising' the balance and spring system where the effect of gravity will make itself most felt. To succeed means that the centre of gravity of the whole system must be maintained on the axis of rotation throughout its entire motion. If there is any slight residual 'heavy spot' or if there is any part of the balance or balance spring 'out of poise' it will, when acted on by gravity, add to or subtract from the forces produced by the balance spring, and cause a change in the rate of the watch.

If the plane of the balance is maintained horizontally, as in a marine chronometer, then the effects of gravity are minimal even if there is a considerable out of poise of the balance. However, in any portable timekeeper worn on the person the plane of the balance will rarely be found to be horizontal, and is more likely to be in a more or less vertical plane in any one of an infinite variety of positions. This will result in the rate of the watch varying over a certain range depending on the actual value of the 'out of poise mass', and the position of the watch.

A. L. Breguet concluded, correctly, that it would not be possible to construct a watch in which the balance and spring system would remain perfectly 'poised' at all times and in all temperatures. He therefore invented one of the most elegant mechanical solutions to a problem ever devised. By placing the balance and spring system together with the escapement inside a rotating carriage driven by the watch, he ensured that the effects of gravity on the whole system would be constantly averaged out. Breguet called this brilliantly clever mechanism, for which he obtained a patent in 1798, a 'tourbillon' (see cat. no. 176).

During the remainder of his life Breguet made tourbillons fitted with a variety of different escapements and rotating at various speeds. Probably the most successful employed the lever escapement and rotated in one minute. He also used the detent, cross detent, his constant force escapement, his 'echappement naturel' and the Robin escapement, and periods of rotation of one, two, four, five and six minutes.

Constructors of tourbillons have tried a variety of periods of rotation of the carriage, from some fraction of a minute to an hour's duration. Many believe that the true tourbillon should have the lever or detent escapement and a period of rotation of one minute but this is too restrictive. In the author's opinion, the essential criterion to differentiate between a tourbillon and a karrusel is that in the former, the carriage is directly driven by the train to transmit the driving force to the escapement. In the karrusel, on the other hand, the driving force to the escapement is transmitted independently of the carriage. It would in fact be possible to disconnect the gearing driving the carriage, whereupon the karrusel would perform as if it had a fixed escapement. This would not be possible with a tourbillon.

The karrusel was invented by Bahn Bonniksen, a watchmaker of Danish origin who lived and worked in Coventry. In 1892 he took out a patent (no. 21421) almost one hundred years after Breguet had patented the tourbillon. A tourbillon designed to rotate once per minute has always been difficult and expensive to make: the entire carriage and escapement must always start from rest and move rapidly forward each time impulse is transmitted to the balance, at the end of impulse the carriage must be halted abruptly. In order to achieve this the carriage must be made as light as possible or its mechanical inertia will prevent it from functioning correctly. Bonniksen's first karrusel had a period of rotation of nearly one hour and was designed to be made by simple mass production methods. It was therefore cheap, and a large number were produced by Bonniksen himself as well as by other makers to whom he supplied ébauches. Later Bonniksen produced another calibre, with a centre seconds hand and a carriage rotating in thirty-four minutes. In practice karrusels gave excellent results, in spite of the slow period of carriage rotation, and were found to be particularly suitable for deck watches. At about the same time as Bonniksen, other makers produced revolving escapements working on either the tourbillon or the karrusel principle, and a number of other patents were taken out.

One of the most remarkable pieces in the museum's collection is signed 'John Arnold No 11' (cat. no. 176). It was originally fitted with Arnold's pivoted detent escapement and was later rebuilt by his friend A. L. Breguet, and fitted with a one-minute tourbillon and cross detent escapement. According to the dedication this was the first tourbillon made by Breguet, but we know that an earlier one was in fact made, with an Arnold detent escapement, and only sold by the firm after Breguet's death.

The collection contains a variety of other tourbillons by Swiss makers, examples of both kinds of Bonniksen karrusel though signed by other makers, and an annular tourbillon by A. Taylor in which the carriage rotates in ten minutes. This last piece is signed 'Carley & Clemence', cat. no. 182.

Ebauches that were unmistakably intended to be precision watches have been included and are all tourbillon or karussel ébauches.

176 JOHN ARNOLD/A. L. BREGUET

1808

TOURBILLON *Plates 140a–f, 141a–d*

Signature: On the back plate, the engraved inscription 'John Arnold London Inv^{t} et Fecit No 11'.

On a silver plate attached to the back plate 'I$^{\text{ER}}$ REGULATEUR A TOURBILLON DE BREGUET RÉUNI A UN DES PREMIERS OUVRAGES D'ARNOLD. HOMMAGE DE BREGUET, A LA MÉMOIRE RÉVÉRÉE D'ARNOLD, OFFERT A SON FILS AN 1808'.

This can be translated as: 'The first Tourbillon regulator by Breguet incorporated in one of the first works of Arnold. Breguet's homage to the revered memory of Arnold. Presented to his son in 1808'.

Case: Engine-turned silver glazed box, the front pushing onto the middle, the glazed back secured by a bayonet fixing and screw, and with an additional cover pushing on. The following marks inside the back cover B over 169 and 2797, also the French quality control mark for 1798–1809. According to Breguet's records the watch was given the number 169 while being worked on. The glazed box was made by Tavernier and numbered 2797, and he was paid various sums at different times for the work involved including 100 francs for supplying the box, 2 francs for silver, 18 francs for engine turning and the sums of 12, 3 and 4 francs apparently for soldering, silver and adjusting the back. Overall diam. 59·3 mm, h. 22·5 mm.

Dial and hands: Silver dial engine-turned, retained by a single screw below XII. It is not clear from the records if the dial was supplied by Tavernier. The engraving was done by Michaud who was paid 8 francs and then 2 francs later for the seconds dial.

The blued steel hands were supplied by Thevenon who was paid 19 francs.

Scratched on the back of the dial 'F [?] L. Weber', erased but still faintly visible 'No. 169'. and 'J.F.C. 9/09'; probably a repair mark (James Ferguson Cole ?).

Movement

Front plate diam. 48·0 mm; back plate diam. 46·2 mm; frame h. 10·3 mm.

Frame: Originally full plate construction with four turned pillars, the back plate retained by pins, and without a detachable barrel bridge. The dial plate has been discarded and the front plate reduced in diameter breaking into the holes for the dial feet. The case catch and spring have also been removed and the holes filled. The movement is now retained in the silver box by three dog screws. The dial is of larger diameter than the front plate and rests on a ledge turned in the case.

The back plate has been cut away leaving most of the original engraving, the holes for the steady pins and screw hole of the original balance cock are hidden under the silver dedication plate. One pillar has been cut off flush with the front plate. The front plate has had the hole for the third wheel enlarged to accommodate a cock for the third arbor upper pivot, and two slots cut under the now fixed fourth wheel, under the tourbillon. A chamfered hole has also been drilled partly under the great wheel for an unknown purpose. The bridge for the third and fourth bearings on the front plate has been cut away and the fixing made precarious at one end, and a hole drilled to expose the gearing between the third wheel and the fourth pinion on the carriage. The frame has been carefully regilded after the alterations, and a dust trap fitted round the winding arbor retained by two small blued steel dog screws.

Fusee: The original keywind fusee fitted with sun and planet maintaining power, as used by John Arnold in his earliest machines and abandoned in favour of the more usual Harrison system in about 1775. The stop-work and setting-up-work fitted between the plates are as in cat. no. 5, except that the block for the stop-pieces has been replaced. The mainspring barrel assembly and the fusee chain are also apparently original. The mainspring could well be that originally fitted by John Arnold, the hooking to the barrel wall does not appear to have been renewed. Spring h. 6·8 mm, th. 0·22 mm. Barrel internal diam. 21·5 mm.

Going train: Only the great wheel, the centre wheel and pinions, and possibly the third pinion, are as originally fitted, the remainder of the train has been completely altered. The great

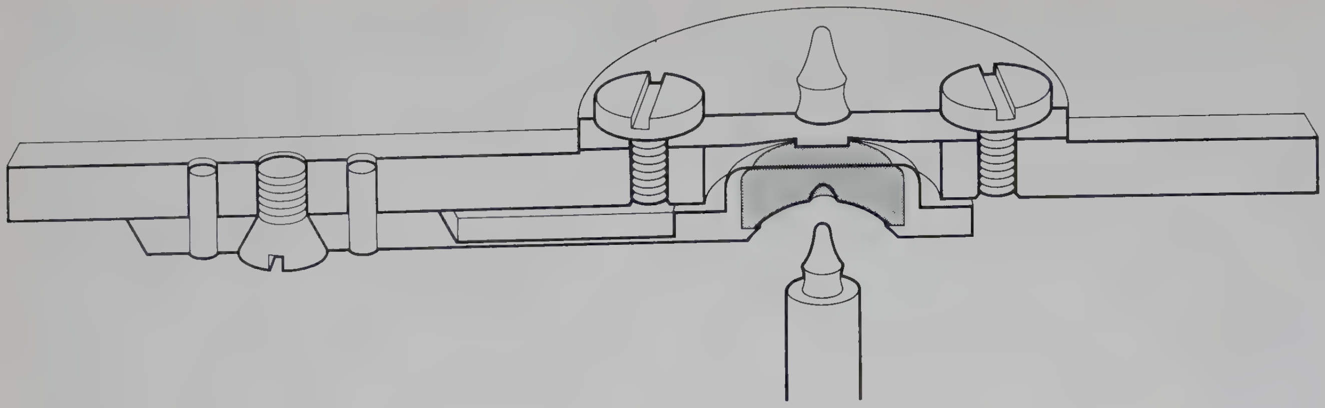


FIGURE 13
Top balance pivot bearing, balance bridge and carriage pivot assembly – A. L. Breguet's tourbillon carriage

wheel, centre and fixed fourth wheel are gilded. The third wheel is plain brass, burnished on both sides, and showing signs of corrosion.

Jewelling: All the going train pivots are run in flat pierced jewels in brass settings themselves set in the plates and held by blued steel screws. The centre and fusee lower and the fusee upper have probably been added by Breguet. Although similar in style to the others, flat jewels without oil reservoirs, the colour of the stones and of the settings are different.

The lower pivot of the tourbillon carriage is apparently run in the original fourth arbor jewel hole. The upper pivot is run in a blind jewel in a resilient jewel setting on the overhanging cock mounted on the back plate. There is a screw to adjust the endshake (see fig. 13). (See further description under Tourbillon and Escapement below.)

Tourbillon: Built up on steel disc with knurled edge, finished grey (diam. 16·3 mm, th. 0·5 mm). The fourth pinion of twenty-five leaves set in a brass collet driven into a boss in the centre of the steel disc, and having the extended seconds pivot on one end and a short piece of the arbor left on the other to limit the movement of the resilient lower balance jewel assembly (see fig. 14).

The upper cone pivot for the carriage integral with a disc 4·4 mm in diameter screwed to the two-armed frame member. The last is wide enough to clear the balance, then waisted in to two feet with steady pins screwed to the knurled disc with two screws. The frame is made from a single piece of steel, bevelled and polished on the top surface, the sides grained (w. 10·5 mm, th. 0·48 mm approx.), the steady pins for it are fixed in the knurled disc.

The balance upper resilient bearing is screwed to the underside of the top cross member of the frame and is set with a jewel having a blind conical hole for the balance upper cone-shaped pivot. The balance lower resilient bearing is screwed to the knurled disc and is jewelled in the same way as the upper, for the balance lower cone-shaped pivot. There is no means for giving any endshake to the balance staff and it is held in compression, gripped between the two bearings. The escape wheel is pivoted between two light steel cocks screwed and steady pinned to the knurled disc, one on each side. Each cock is set with a very small diameter pierced jewel, allowing very little room for the oil reservoir.

The carriage is poised by a platinum screw set in the knurled disc, and part of the disc is pierced out near the escape wheel. The whole construction is both light and strong, and the workmanship of a very high order. The shock protection afforded by the resilient balance bearings and carriage upper bearing is such that the watch could easily survive a heavy fall without damage to any part of the tourbillon (see fig. 14). From the records it appears that the maker of the tourbillon was probably Renevier, who received 100 francs.

Escapement: Peto cross detent escapement with steel escape wheel. The detent screwed to a separate bracket on the knurled disc. The slot for the locking stone open towards the gold banking screw, and the stone itself of square section providing a surface against which to bank. That part of the stone projecting above the detent is ground to a triangular section to clear the escape wheel teeth on the return of the detent after unlocking. The steel passing spring, integral with its foot screwed to the knurled disc, acts on a gold pin standing up from the end of the detent horn. Both impulse and discharge rollers jewelled on their acting surfaces. The impulse roller jewel leaning towards a radial from the roller centre to its tip (compare with Brockbanks, cat. no. 72).

The escapement jewels were supplied by Pellet who received 48 francs, and its seems likely that Michel Weber, who was paid 342 francs; was responsible for fitting together and adjusting the escapement and tourbillon.

Balance: Bimetallic three-armed balance, the screws for poising, timing and compensation of red gold. Diam. of rim 19·9 mm, h. 1·24 mm.

Balance spring: Blued steel spiral spring with overcoil and terminal curve mounted upside down under the balance on a brass collet. The steel stud having a square hole and pin to secure it to the spring, the former fixed to the knurled disc by a single screw but with three more screws for levelling.

Going-train counts:
Great wheel (fusee) 48 teeth
Centre pinion 12 leaves, wheel 75 teeth, no crossings

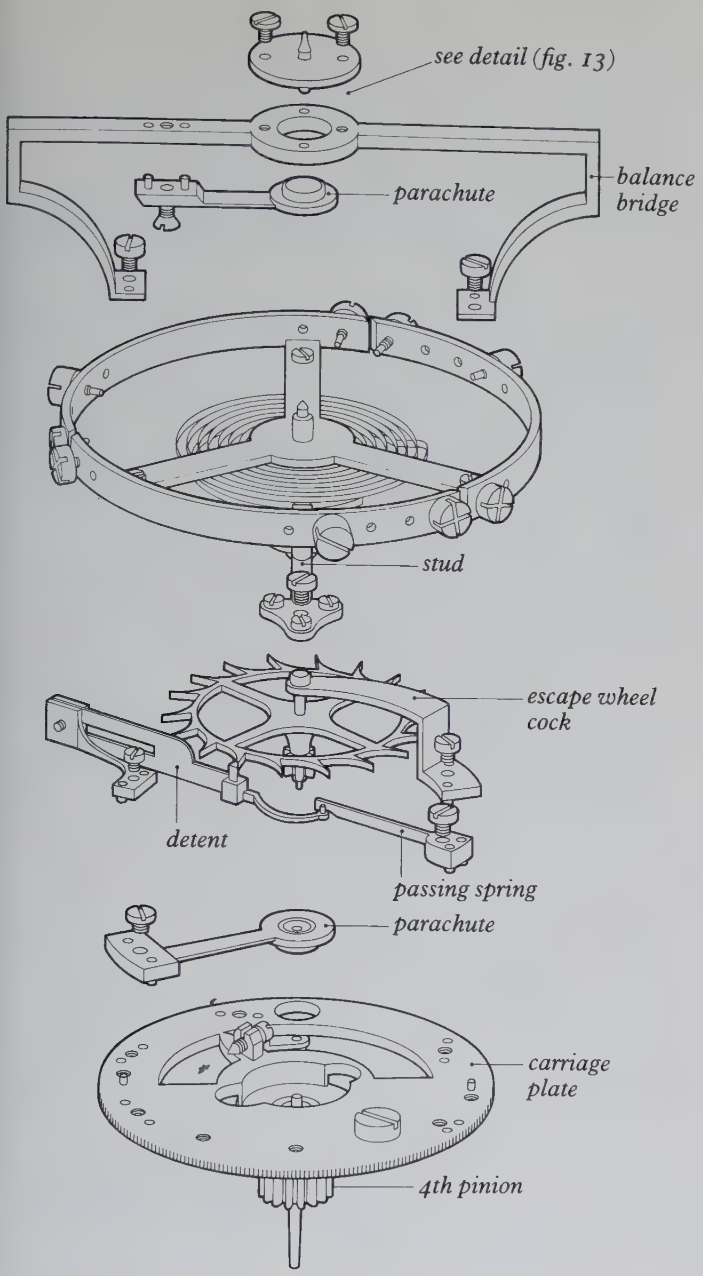


FIGURE 14
A. L. Breguet's tourbillon carriage, an exploded view

Third pinion 8 leaves, wheel 96 teeth, 4 arms
Fourth pinion 15 leaves, wheel 60 teeth, solid
Escape pinion 6 leaves, wheel 18 teeth, 4 arms
Beats per hour, the unusually high number of 21,600

Motion work:
Cannon pinion 16 leaves, minute pinion 20 leaves, blued
Hour wheel 60 teeth, minute wheel 64 leaves

The minute wheel is gilded, the steel minute pinion blued and adjusted onto a tube on the minute wheel. The steel cannon pinion is waisted and slotted. The hour wheel is not gilded.

Provenance: The original watch made by John Arnold dates from 1774 or 1775; his No. 14 is dated 1775. According to the inscription on the silver plate attached to the back plate, the watch was fitted with a tourbillon mechanism and presented to John Roger Arnold in 1808. According to information supplied by the firm of Breguet, this watch and another tourbillon given the number 282 and also inscribed that it was the first tourbillon made by Breguet, were both made in 1808. They also state that John Roger Arnold received the watch on 30 August 1809. Ilbert Collection; purchased by Ilbert in 1933 (reg. no. CAI-1848).

Exhibited: Musée International d'Horlogerie, La Chaux-de-Fonds, Switzerland, May–September, 1976, see exhibition catalogue, pp. 32 and 33.

Note: Breguet's records relating to the work of conversion of John Arnold No. 11 and the construction and fitting of the tourbillon mechanism. Free translation and interpretation by the author:

Work done	*Work done by*	Cost in Francs
movement of a watch by Arnold		336
escapement (tourbillon?)	Renevier[1]	300
case 2797	Tavernier	100
tipsy key (?)	Winisch	7
engraving of the figures on the dial	Michaud	8
gilding	Guerau	3
wheel	Sandoz	4
two holes (jewels?)	Nocker	24
colouring dial (rough dial?)	Cherrier	2
escapement jewels	Pellet	48
drilling the front glass	Robert	15
engraving of the seconds ring	Michaud	2
hands	Thevenon	15
silver	Tavernier	2
repaired 2 holes	Pellet	6
engine turning	Tavernier	18
balance	Courtin	42
checking	Weber[2]	000
adjusting or correcting	Pellet	2
a jewel	Pellet	2
screws	Courtin	4
soldering of joints	Tavernier	12
silver	Tavernier	3
cutting the back	Tavernier	4
polishing two wheels	Paris	1
drilling a glass	Robert	5
checking (might mean assembly and making go)	Weber[2]	342
engraving	Michaud	50
		1357

Timekeeper, jewelled train, silver box
In charge Weber – Box by Tavernier No. 2797
The work was carried out between January 1808 and May 1809
Given as a present to Mr Arnold, the 30th August 1809.

1. Renevier was apparently Swiss and worked for Breguet et Le Locle with another workman from Geneva called Juntes until 1796 (see A. Chapuis and E. Jaquet, *History of the Self-Winding Watch*, Neuchâtel, 1952, p. 84).
2. Michel Weber, one of Breguet's most gifted pupils, was made responsible for the Marie Antoinette watch, No. 160 (Clutton and Daniels 1965, p. 61).
3. Thanks are due to the firm of Chaumet for this information.

Bibliography: Reinhard Meis, *Das Tourbillon*, Munich, 1986, pp. 88, 89.

177 HUNT AND ROSKELL

1836

TOURBILLON *Plates 141e–f, 142a–f, 143a–c*

Signature: On the back plate 'Hunt & Roskell 156 New Bond Street LONDON No 10514'.

Case: Gold open face, with the London hallmark for 1836 and the maker's mark P.M. Solid pendant without push-piece also with 18-carat mark, no fly springs. The middle decorated with reeding, the glazed bezel, cuvette and back hinged to the middle. The back marked as the back plate. Blocks fitted in the middle for the case screws to purchase on. Diam. 58·7 mm, h. over the glass 20·4 mm.

Dial and hands: Flat enamel dial attached to the front plate by two feet and screws on the inside of the plate. Central minute hand, with subsidiary seconds and hours on the upper left- and right-hand sides of the dial respectively. Thermometer graduated in the Fahrenheit and Reaumur scales of temperature in the bottom half. The glass is recessed in the middle on the inside, over the centre arbor.

Blued steel hands with crescent tails.

Movement

Front plate diam. 53·3 mm; back plate diam. 49·7 mm; frame h. 12·2 mm.

Frame: Three-quarter plate with three tapered turned pillars, the back plate retained by blued steel screws. The movement retained in its case by a positioning peg and three large polished steel dog screws. A chain guard fitted between the tourbillon carriage and the barrel, screwed to the underside of the back plate. The tourbillon carriage support at the top, a cock. Another cock carries the upper fusee bearing.

Fusee: Keywind fusee with continental stop-work and Harrison maintaining power. The maintaining ratchet wheel steel, the maintaining detent polished steel and pivoted in the frame, the return spring a piece of steel wire set in a screw and pointing down from the top plate. The setting-up-work mounted on the back plate, both ratchet and wheel polished steel, the ratchet held by a shoulder screw. The barrel arbor squared on one end only. The mainspring hooked to a brass peg in the barrel wall and with a steel bride lodged in the cover and bottom of the barrel. The very fine blued mainspring, signed *Bandelien Frères*, showing little sign of wear. The barrel fitted with the cover towards the front plate.

Going train: Well-made train with gilded brass wheels and polished pinions, arbors and pivots, arranged for the comparatively high count of 21,600 beats per hour. The fixed fourth wheel held by three screws. A brake operated by a push-piece near the pendant acts on the rim of the third wheel.

Jewelling: The pivots of the centre, third, tourbillon and escapement arbors in rubbed-in pierced jewels of a whitish pink colour. The escape pinion arbor and balance staff with endstones.

Tourbillon: The carriage revolves once per minute and is driven by the third wheel, acting on the fourth pinion fixed to the bottom of the tourbillon frame. The fixed fourth wheel concentric with the carriage meshes with the escape pinion. The steel carriage frame is built up on a pierced plate with two wide pillars of flat section supporting a single member across the top with a raised portion for the upper pivot, the upper balance pivot bearing and to carry the balance spring stud. The entire frame, the cocks for the escape wheel bearings and the detent mounting are finished with an almost blemish free mirror black polish. This includes the underneath of the carriage, the inside surfaces of the pillars, and all the bevelled edges on the upper surfaces, a truly marvellous feat of craftsmanship.

Escapement: Spring detent escapement of Earnshaw type. The gold escape wheel recessed on the underside leaving only the teeth the full thickness. The tooth form similar to that used by Earnshaw. The detent with pierced return spring, half-round locking jewel, and gold passing spring pinned in a block on the detent. The passing spring thinned near its pinning point. The detent foot planted on or near to a tangent to the locked wheel tooth. The polished steel impulse and discharge rollers both jewelled. The impulse pallet leaning towards a radial from the roller centre to the tip, so that the leading edge of an escape wheel tooth and the impulse surface of the pallet lie on a straight line, or nearly so, at the beginning of impulse. The impulse roller with poising holes drilled opposite the pallet. Banking for the detent provided by a steel piece with an adjusting screw forming part of the detent mounting, itself screwed to the frame. The detent positioned by a friction-tight adjustable dovetailed tongue.

Balance: Bimetallic two-armed balance with gilded brass segment weights, the rims graduated with a series of dots. The movement of the free ends of the rims limited by gold nuts on threaded studs passing through clearance holes for the threads in the rims into gold blocks screwed to the ends of the balance arms. Gold timing screws at the ends of the arms passing through the rims into the same gold blocks. Screws in the side of the segment weights for fine adjustment of the compensation. Diam. of rim 18·7 mm, h. 2·02 mm.

Balance spring: Blued steel spherical balance spring, free sprung to a stud fixed to the upper frame member of the carriage.

Thermometer: Rack and pinion with spiral return spring operated by a U-shaped bimetallic strip. Compare with the similar metallic thermometer signed 'Urban Jürgensen Invenit et Fecit'.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 14 leaves, wheel 80 teeth, 6 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms

Fourth pinion 10 leaves, wheel 72 teeth
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 21,600

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Webster in 1930 (reg. no. CAI-299).

Note
The movement at least of this watch was made in Switzerland. Alfred Chapuis (see *Bibliography*), illustrates a similar watch signed Du Bois et Cie, which he attributes to J. F. Houriet (1743–1830) in about 1820. Houriet invented the spherical balance spring to reduce the effects of any decentralisation of the spring. He would have been 77 in 1820.

Another similar watch in the museum of Le Chaux-de-Fonds, but having concentric central minute and hour hands, is signed 'Frédéric Louis Favre-Bulle' who lived from 1770 to 1849. In the same museum there is also another example with a similar dial arrangement to that illustrated here, but with the seconds and hour subsidiary dials interchanged. It is signed on the dial only 'Urban Jurgensens Sönner', and dated about 1810.

Bibliography: Alfred Chapuis, *Les Grands Artisans de la Chronométrie*, Neuchâtel, 1958.

178 CHARLES SUCHY & FILS

c. 1875

TOURBILLON *Plates 143d, 144a–e, 145a–b*

Signature: On the çentre arbor bridge 'Ch. Suchy & fils.' On the underside of the tourbillon carriage 'Ernest Guinand au Locle' (died 1879).

Case: Plain silver hunter case numbered 26403, the Swiss silver quality mark 0,900 and a bear with the letter L in separate cartouches, on the cover and both backs, L the mark for Le Locle. A large heavy pendant, also with a bear, and gold-covered winding button with central push-piece to operate the case lock spring. The front cover opened by a single fly spring, to reveal a glazed bezel protecting the dial and hands. Diam. 55·4 mm, overall h. 15·5 mm.

Dial and hands: Flat enamel canister dial with sunk subsidiary seconds snapped into a nickel ring, itself snapping onto the edge of the front plate, and with one positioning peg.

The matching minute and hour hands set with small faceted paste stones and, like the seconds hand, apparently made of red gold. The seconds hand shaped as an arrow.

Movement
Ebauche marks 26403.

Front plate diam. 44·5 mm; front plate th. 3·9 mm (reduced to 2·3 mm under dial); frame th. 8·8 mm; tourbillon h. across pivot shoulders 7·75 mm; tourbillon overall diam. 18·8 mm; h. of tourbillon frame 3·85 mm.

Frame: Similar to that by Pellaton (cat. no. 181) and almost certainly from the same supplier. The material of the frame is nickel brass and the surface finish a series of ring patterns with snailing radiating from the centre. The movement fixed in its case by three dog screws in the edge of the front plate under the dial, and with a positioning peg.

Going barrel and keyless work: Similar to cat. no. 181, except that the hand-set lever operating piece is polished steel.

Going train: Similar to cat. no. 181, but the wheels made of red gold.

Jewelling: The pivots of the centre, third, tourbillon and escapement arbors in pierced jewels, those of the balance staff with endstones. The third and fourth arbor lower jewels, set in a separate bridge, with curved surfaces towards the pivot shoulders. The third arbor upper jewel set directly in the front plate, and not in a separate cock as cat. no. 181. The centre jewel in the bridge in a screwed setting, the screws with polished steel cup washers.

Tourbillon: Makes one revolution per minute and carries the seconds hand on an extended lower pivot. The steel carriage built up on a polished steel plate with three pillars carrying the upper pierced framework. All the upper and lower surfaces of the carriage polished, and with polished bevelled edges. Separate cocks pinned and screwed to the steel plate carry the bearings for the escape and detent arbor pivots. The fourth pinion driven into a polished steel disc screwed and pinned to the underside of the steel plate. The lower balance bearing a pierced jewel setting screwed into the disc with the fourth pinion on the other side. The endstone rubbed into its setting on the end of the pinion. The balance upper pierced jewel rubbed into the material of the steel pierced framework, with the endstone in the boss with the upper carriage pivot on the other side. The index pivots and is held on a taper on the edge of this boss. The carriage is not properly poised although two steel poising screws are fitted opposite the escapement on the steel plate. Engraved on the bottom of the carriage is the signature 'Ernest Guinand au Locle'.

Escapement: Pivoted detent escapement with the first tooth after that which has just given impulse locking on. The thin red gold escape wheel lightly crossed out, and burnished on both sides. The steel impulse roller polished all over, and with a radial impulse pallet. The discharge roller and pallet made from a single piece of ruby. The pivoted detent with a spiral return spring, short counterpoising tail, later gold passing spring held by a screw in the edge of the detent boss and a half-round locking stone. Banking is provided for the steel boss round the locking stone against the head of a gold screw set in the steel tourbillon plate.

Balance: Bimetallic two-armed balance with gold screws, the arms of sage-leaf shape, and joining the rim halfway up the inside, no quarter screws for timing purposes. Diam. of rim 15·1 mm, h. 1·38 mm.

Balance spring: Blued steel spiral spring of 13½ turns with an overcoil and terminal curve, pinned to a polished steel stud screwed to a cross-member of the upper part of the carriage frame. A round polished steel collet on the balance staff. The tail of the index moving over a gold scale screwed to the upper carriage frame.

Amplitude limiting device: Similar to cat. no. 181.

Going-train counts:
Great wheel (barrel) 96 teeth
Centre pinion 12 leaves, wheel 96 teeth, 5 arms
Third pinion 12 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 70 teeth, fixed with two screws
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

The cannon pinion is integral with its arbor which passes through the hollow centre pinion and is fixed by a polished steel ring and a transverse pin.

Keyless work:
Crown wheel 24 spur, 14 ratchet teeth
Castle wheel (sliding pinion 14 ratchet teeth, 28 bevel teeth)
Intermediate winding wheel 38 spur, 32 bevel teeth
Barrel ratchet wheel 47 teeth
Intermediate hand-set wheels, each 18 teeth

Provenance: Ilbert Collection; purchased by Ilbert in 1933 (reg. no. CAI-1835).

Note

Apart from the keyless work which seems to have come from a different source, the ébauche appears to be identical to that used by Pellaton (cat. no. 181). The fourth wheel to escape pinion gear ratio is also different, giving a different number of beats per hour of the balance, but with the same centre distance, and the same module, about 0·13, for the gearing. The centre distance is therefore the same for the escape wheel to balance, but the escapement proportions chosen by the two makers are not the same.

179 JULES CALAME ROBERT

c. 1880

TOURBILLON MOVEMENT *Plates 145c–d, 146a–d*

Signature: On the barrel/fusee bridge 'J^{s} Calame Robert CHAUX DE FONDS'. On the balance cock 'Tourbillon'.

Dial and hands: Flat enamel dial with sunk subsidiary seconds and day of the month dials, retained by two small screws passing through the dial at the edge and into the front plate. The back of the dial marked 94575 R and with two copper feet cut off flush.

Blued steel minute and hour hands, the seconds and calendar hands missing.

Movement

Stamped on the front plate under the dial 'J. Calame Robert Chaux de Fonds' and '94575'.

Front plate diam. 47·0 mm; front plate th. overall 3·8 mm (front plate th. reduced to 2·62 mm under dial); frame h. 9·9 mm.

Frame: Built up on a massive front plate. A large bridge carries the upper bearings for the barrel, fusee and centre arbor, with separate cocks for the other bearings including the maintaining detent. A large bridge on the front plate under the dial carries the lower bearings of the third and tourbillon arbors.

The movement was fixed in its case by a peg and two dog screws in the edge of the front plate. All the brass parts gilded.

Fusee: Keywind reversed fusee with Harrison's maintaining power, the maintaining ratchet wheel of steel. A five-turn Geneva stop-work fitted in a shallow recess on the front plate and operated by the fusee arbor. Setting-up-work similarly fitted, the barrel arbor with an extended square on that end only, the ratchet with two teeth as in later marine chronometer practice. A chain guard is provided between the barrel and the tourbillon to protect the latter in the event of the chain breaking. The barrel flanged on the end remote from the cover. The fusee arbor having a boss on which the great wheel pivots, with a plate held by three screws in a recess on the outside of the great wheel to hold the assembly together. Mainspring 4·10 mm × 0·16 mm. Barrel internal diam. 16·8 mm.

Scratched on the outside of the outer end: '16 Lignes'. A loose bride fitted near the outer hooking.

Going train: Arranged in the usual way for a one-minute tourbillon. The centre wheel below the great wheel, the third wheel on the dial side of the front plate engaging with the fourth pinion on the tourbillon axis. The escape pinion pivoted on the edge of the carriage and meshing with the fourth wheel screwed to the back plate concentric with and below the tourbillon. The well-made train with brass wheels gilded, the steel pinions and arbors nicely finished and polished. The centre arbor hollow for the squared hand-set arbor carrying the cannon pinion.

Jewelling: The pivots of the third, tourbillon and escapement arbors in pierced jewels, those of the escapement with endstones. The upper third and carriage jewels in screwed settings. The train jewels *bombé* with curved faces against the pivot shoulders.

Tourbillon: Making one revolution per minute and carrying the seconds hand on an extended lower pivot. The carriage built up on a steel plate with three pillars carrying the upper pierced framework. Most unusual pillars only 0·5 mm in diameter with a broad base and a cantilevered arm at the top to screw into. A separate bridge encircling the balance staff carries the upper escapement bearings at its ends and is carried on three short integral pillars. A separate polished steel disc carrying the fourth pinion and the balance lower endstone in a brass setting is attached by three screws only to the bottom of the carriage. All the upper steel surfaces with bevelled edges are highly polished. The carriage is not properly poised and has a pronounced heavy spot opposite the escapement.

Escapement: Club-toothed lever escapement with divided lift, the pallet stones with curved impulse faces set in slots in the material of the polished steel fork which also has a short tail banking between two polished steel pins. The steel escape wheel polished on both sides, the impulse faces chamfered both sides, the wheel very lightly crossed out. The fork and roller axis at right angles to the wheel and pallet axis. A single roller with an oval impulse jewel, providing safety action with a V-shape filed in the material of the fork immediately before the notch.

Balance: Bimetallic two-armed balance, the arms of 'sage-leaf' pattern, the rims set with brass screws. The balance sunk out on both sides, leaving the arms midway between the top and bottom of the rim. Diam. 16·8 mm, h. 1·2 mm.

Balance spring: Blued steel spiral spring of 16½ turns with an overcoil and terminal curve having a reversed curve, pinned to a polished steel stud and a round brass collet. An index is provided, concentric with the central boss of the upper part of the tourbillon carriage frame.

Day of the month indication: A wheel on the same axis as and above the hour wheel drives another with double the number of teeth. This second wheel, turning on a steel pillar, carries a pin to index a star wheel every twenty-four hours. The day of the month hand is carried on the extended arbor of this wheel.

Going-train counts:
Great wheel (fusee) 70 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 72 teeth, no crossings
Escape pinion 8 leaves, wheel 15 teeth, 4 arms
Beats per hour: 16,200

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth
First calendar wheel on the hour wheel 21 teeth
Second calendar wheel 42 teeth
Star wheel 31 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1138).

Note: In Ilbert's inventory notebook, stuck on the page opposite the entry for this watch, is a letter from Paul Ditisheim:

> 32, Rue du Ranelagh (XVI^{E})
>
> Autevil 14–68 PARIS LE Aug 8th 1936
> Dear Paul
>
> My letter was just dispatched when I received your good news of July 28th.
>
> I can give you full information, over Jules Calame Robert, who has been acting as watch manufacturer, later on with his two sons at La Chaux de Fonds, for over 50 years. One of the junior members was active in political and corporative associations (Jules Calame Colix) and for a number of years President of the Society des fabricants d'Horlogerie de la Chaux de Fonds.
>
> This manufacture was in the old system of buying the rough work Fontaine Melon and others in the period 1850–1900. As regards the tourbillon picked up by M. Ilbert. The tourbillon work is *whether by Albert Pellaton Le Locle or by Auguste Grether* Ponts de Martel, specialists acting during the later part of the above mentioned period.
>
> The firms seat was 4 Rue de Parc and later on the sons built a small factory close by (no. 2). My brother Henry bought both buildings direct from them when they retired as well to do people to Corcelles near Neuchâtel.
>
> We are very pleased you keep very busy with guests and Horology in your summer resort. Many thanks for your sending the papers I am looking forward for the September Horology number which we now receive regularly at the Laboratory. We are going to spend a fortnight at Lepoy a little village of Loiret (90 miles away). We all three are joining in kindest regards to Mrs Chamberlain and to you.
>
> Your affectionate
> Paul Ditisheim

180 MAKER UNKNOWN, but Swiss
Late 19th century

TOURBILLON MOVEMENT *Plates 147a–f, 148a–b*

Dial and hands: Flat enamel dial with sunk subsidiary seconds. The space between the hour markings decorated with a very faint pattern in the enamel based on a fleur de lis motif. The centre of the subsidiary seconds dial similarly decorated but with a geometrical design and bolder. The canister-type dial snapped into a nickel ring itself snapping onto the edge of the front plate, and with a single positioning peg.

Blued steel hands, the seconds hand purple.

Movement
Ebauche marks 20419
Front plate diam. 45·6 mm; back plate diam. 44·0 mm; frame h. 9·0 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate secured with recessed polished steel screws. A bridge on the recessed front plate under the dial carries the lower third and tourbillon arbor bearings. Top bearing in a cock, the jewel in a screwed gold setting. The tourbillon is protected by a chain guard between itself and the barrel. The movement was secured in its case by a peg in the edge of the front plate, and two dog screws accessible from under the dial. All the brass parts appear to have been electro-gilded a whitish colour.

Fusee: Keywind fusee fitted with Geneva stop-work on the dial side of the front plate and Harrison's maintaining power. The maintaining ratchet wheel steel. The fusee arbor upper pivot is run in a large bush protruding below the back plate and with a dust tube on the other end secured in a recess by three screws. Setting-up-work on the front plate under the dial, the barrel arbor with an extended square on that end only. A flange on the cover end of the barrel.

Going train: Laid out as for a one-minute tourbillon, but with the third arbor upper bearing in the back plate instead of a separate cock under the carriage. The centre pinion hollow for the squared hand-set arbor carrying the cannon pinion. The fourth pinion mounted on a boss screwed to the bottom of the carriage, and with an extended fourth pivot for the seconds hand. The steel pinions and arbors finished and polished to a fair standard, the brass wheels electro-gilded over a granular finish. The fixed fourth wheel secured by two screws and with two steady pins.

Jewelling: The upper pivot of the centre arbor and those of the third and carriage in pierced jewels in gold screwed settings.

The escape arbor and balance staff pivots in pierced jewels with endstones.

Carriage: The lower frame member made of nickel and its cock made of nickel brass. The three pillars and the upper frame member made of polished steel. Each pillar having two screws at each end securing the frame members. The lower balance bearings fitted into the boss carrying the fourth pinion and secured to the lower frame member by three screws and two steady pins. The upper balance pierced jewel set in a brass ring held by two screws from the underside of the upper frame member. The endstone set in a steel boss secured by three screws and three steady pins. The finish on the steel parts is good but marred by many fine scratches, suggesting that these parts were not sufficiently hardened. Several of the screws are stripped, particularly where threaded into nickel brass. The carriage poised by virtue of the asymmetrical design of the lower frame member.

Escapement: A development of Earnshaw's spring detent escapement. The gold escape wheel very lightly made and with the arms and rim sunk below the level of the teeth. Locking occurs on the second tooth after the one which has just given impulse, an unusual feature of this type of escapement. The detent is planted with its foot at right angles to the spring so as to give the maximum effective length to the detent. The detent angle outside a tangent to the locked tooth, and there is only a small amount of draw. The ruby locking stone is of D-shaped section. The passing spring of gold is held with a screw, banking the detent with its head against a foot screwed to the lower carriage frame. The polished steel impulse roller has a jewel with its impulse face radial to the roller centre. The discharge roller is made from a solid piece of ruby.

Balance: Bimetallic two-armed balance, the arms of sage-leaf pattern, positioned midway in the rim. Gold screws and quarter nuts. Diam. of rim 14·2 mm, h. 1·40 mm.

Balance spring: Blued steel spiral spring of approximately 15 turns, with an overcoil and terminal curve having a reversed bend, free sprung to a self-aligning stud clamped under a polished steel plate with two screws, and a round brass collet.

Going-train counts:
Great wheel (fusee) 76 teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 70 teeth, no crossings
Escape pinion 7 leaves, wheel 15 teeth, 4 arms
Beats per hour: 18,000

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Bevan in 1937 (reg. no. CAI-3135).

181 MAKER UNKNOWN, but Swiss

c. 1900

TOURBILLON MOVEMENT *Plates 148c–d, 149a–d*

Signature: None, but probably made by either Albert Pellaton-Favre (1832–1914) or his son James César Pellaton (1873–1954).
Case: Missing, but was a hunter case.

Dial and hands: Flat enamel dial of canister type and of a greenish blue, with white sunk subsidiary seconds.

Blued steel hands, the seconds a later replacement.

Movement
Ebauche marks 3009, 38, 1 on the front plate under the dial (see also Charles Suchy et Fils, cat. no. 178).

Front plate diam. 44·2 mm; back frame diam. 42·3 mm; frame th. 8·4 mm; front plate th. 4·3 mm (reduced to 3·1 mm under dial); carriage diam. 19·0 mm; h. over pivot shoulders 7·74 mm; frame h. 4·18 mm.

Frame: Bridge calibre built up on the front plate, the curved centre wheel bridge is characteristic of the work of the Pellatons. The large sub plate on the front plate under the dial carries the third arbor and tourbillon lower bearings and provides a maximum of height within the frame. The movement was fixed in its case by a peg and dog screw in the front plate. The material of the frame is maillchort, a type of nickel brass, or nickel silver as it is usually called.

Going barrel and keyless work: The going barrel, also of nickel brass, with four-turn Geneva stop-work on the cover end. Sliding pinion keyless work, the hand-set mechanism operated by a lever with gold touch piece on the edge of the dial at IV o'clock.

Going train: Arranged for a hunter calibre. The centre arbor hollow for the arbor carrying the cannon pinion. The centre wheel planted below the barrel, the third wheel below the centre and meshing with the fourth pinion on the bottom of the carriage. The escape pinion planted in the carriage and meshing with the fourth wheel fixed concentric with and under the carriage.

Jewelling: The centre upper pivot runs in a jewel with screwed gold setting, those of the third, the tourbillon and the escapement arbors also in pierced jewels. Those of the escapement with endstones. The jewels for the carriage pivots *bombé*, with convex surfaces against the pivot shoulders.

Tourbillon: Making one revolution per minute and carrying the seconds hand on its extended lower pivot. The carriage top pivot supported by a steel bridge, the jewel in a screwed gold setting. The carriage lightly constructed on a steel plate reduced to a thin rim with three integral arms joining it to the central boss. Three turned pillars at the ends of the arms on the rim carry the three upper arms and integral central boss. The two central bosses have the balance jewelled bearings set inside them. The lower boss also carries the fourth pinion set in a nickel ring and secured by three screws. The escape wheel arbor is carried between cocks branching off one of the arms of the lower part of the frame, opposite it on the rim is screwed a small platinum block acting as a poising weight. The carriage is, however, badly out of poise.

Escapement: Spring detent escapement of developed Earnshaw type. The very light escape wheel with arms sunk below the level of the rim and teeth apparently made of gilded brass. The steel impulse and discharge rollers polished all over and each jewelled radially, the jewels set in straight-sided slots. A most delicate locking detent having its foot at right angles to the main axis, screwed to the rim of the carriage and planted so that the main axis is on or near a tangent to the locked tooth. Both the detent horn and the end of the gold passing spring, itself held by a screw to the detent, are bent towards the balance centre. Banking for the detent provided by an extension of the locking stone below the detent against a narrow arm left standing from the boss of the lower part of the tourbillon frame. The locking stone so reduced that in section it is less than semicircular. The spring part of the detent consisting of two narrow strips joining the detent body by the passing spring boss to the foot.

Balance: Bimetallic two-armed balance, the arms of sage-leaf shape, set above the bottom of the rim. The screws gold, no quarter screws. Diam. 17·0 mm, h. 1·2 mm.

Balance spring: Blued steel spiral spring of 13¾ turns, with an overcoil and terminal curve. A steel stud held with a single screw and steady pin on a short bracket between one of the arms and the boss of the upper part of the carriage. A round nickel collet. Carried on the central boss of the upper part of the carriage is a regulator index, its tail passing over a sector left integral on one of the arms.

Amplitude limiting device: As the balance swings, a pin standing from the upper side of one balance arm passes between two pins pointing down from one of the arms of the upper part of the tourbillon frame. An arm pointing outwards from a tiny block pinned to the last turn of the balance spring moves out across the two pins in the tourbillon frame and prevents the pin on the balance from passing between the pins a second time in one direction of rotation of the balance. Should the amplitude of the balance increase unduly, the resulting interference between the arm on the block and the pin on the balance reduces the amplitude to the normal and safe limit.

Going-train counts:
Great wheel (barrel) 96 teeth
Centre pinion 12 leaves, wheel 96 teeth, 5 arms
Third pinion 12 leaves, wheel 90 teeth, 5 arms
Fourth pinion 12 leaves, wheel 72 teeth, no crossings
Escape pinion 6 leaves, wheel 15 teeth, 4 arms
Beats per hour: 21,600

Motion work:
Cannon pinion 12 leaves, minute pinion 10 leaves
Hour wheel 40 teeth, minute wheel 36 teeth

Keyless work:
Crown wheel 25 spur teeth, 13 ratchet teeth
Castle wheel (sliding pinion) 13 ratchet, 27 bevel teeth
Intermediate winding wheel 41 teeth
Barrel ratchet wheel 46 teeth
Intermediate hand-set wheels, each 15 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1954 (reg. no. CAI-882).

Bibliography: James C. Pellaton, *Le Tourbillon*, Editions des Annales Françaises de Chronométrie, Paris, 1951, p. 355, fig. 13.

182 CARLEY AND CLEMENCE

1903

TAYLOR TOURBILLON *Plates 149e–f, 150a–d, 151a–b*

Signature: Carley & Clemence Ltd 30 Ely Place London E.C. No 51619'. On the mechanism the British Government property mark.[1]

Case: Open face silver case with inner dome and back hinged to the middle. London hallmark for 1903, the number 4, and the casemaker's mark C & C$^{\text{LD}}$ (for Carley and Clemence Ltd) in an oval cartouche.

The glazed silver deck watch case with large hand-set push-piece, no pendant ring (or provision for one) and rolled gold winding button fits into a brass drum with glazed screw-on bezel, contained in a polished wooden box. The box has an inlaid ivory disc 'CARLEY & CLEMENCE LT$^{\text{D}}$ (with the British Government property mark) 51619 P.C.', and has been altered so that it no longer has a separate glazed lid. Case diam. 60·0 mm, h. 21·0 mm. Box 103·5 × 129 × 65·6 mm.

Dial and hands: Enamel canister dial. The dial inscribed 'Carley & Clemence Ltd 51619' and the British Government property mark. The dial marked with 0·4 second intervals as well as seconds. Since the watch is single beat the centre seconds hand will register over these marks.

Blued steel hands, including centre seconds hand.

Movement

Ebauche marks on the front plate under the dial A.T in a rectangle and the number 51619. A. Taylor of Coventry took out a patent, No. 16623, on 5 September 1895, for a tourbillon mechanism. That fitted in this watch is similar, but is not the same as that described in the patent.[2]

Front plate diam. 48·0 mm; back plate diam. 46·1 mm; front plate th. 4·0 mm; frame h. 11·3 mm.

Frame: Half plate construction with three turned pillars mounted on the massive front plate, the back plate secured by blued steel screws.

The carriage of the tourbillon pivoted between the front plate and a pierced bridge supported on two turned pillars.

Going barrel and keyless work: English rocking bar keyless work. The going barrel with five-turn Geneva stop-work, the back plate with a raised portion to accommodate the extra height of the barrel.

Going train: Conventional train with offset centre arbor, as far as the fourth pinion which is planted at the centre. Another pinion on the fourth arbor drives a toothed ring on the underside of the carriage. The teeth of a fifth wheel, mounted on the carriage about halfway in from the edge, mesh with those cut internally on a fixed ring concentric with the carriage centre. The fifth wheel's teeth also mesh with and drive a pinion, planted at the centre of the carriage, on which is mounted a sixth wheel meshing with and driving the escape pinion. The total number of wheels in the going train, including the great wheel on the going barrel, is therefore seven and the total number of pinions is six. A conventional going train has four wheels and four pinions.

Jewelling: All the going train arbor pivots run in pierced jewels, from the offset centre arbor to the arbor of the wheel at the centre of the carriage, except the central fourth arbor lower pivot which runs in a brass bush. The escapement arbor pivots run in pierced jewels with endstones, the balance upper being a diamond.

Tourbillon: The brass carriage turns once in ten minutes and is made up of a number of brass parts. The main plate is recessed on the upper side and has a fixed toothed ring fitted friction tight on the boss on the underside. A further sub frame on the underside with the carriage lower pivot and the lower bearings for the fifth, sixth and escape arbors, has three pillars passing through holes in the main plate. A bridge in the recess on the upper side of the main plate has holes fitting over the ends of the pillars and is retained by three screws going into threaded holes in the pillars. The main plate is therefore sandwiched between this bridge and the lower sub frame. In the bridge are lodged the upper bearings for the fifth, sixth and escape arbor pivots, these arbors passing through clearance holes in the main plate. The balance bridge fits onto three pillars on the edge of the upper surface of the main plate and carries the upper carriage pivot. The carriage is poised, metal having been removed from a slot in the underside of the main plate. The workmanship necessary to make the carriage and all its parts with a sufficient degree of truth, so that it can be entirely dismantled for cleaning, is of the highest possible order.

Escapement: Earnshaw type of spring detent escapement, the escape wheel of gold, the steel impulse roller not jewelled but polished all over. The impulse plane on a radial from the roller centre. Polished steel banking piece for the detent, with a gold banking screw. The diminutive detent, only 10·5 mm long overall, is screwed in a slot in the main plate of the carriage to a polished steel plate also screwed to the edge of the main plate from underneath. The passing spring is gold and attached to the detent by a screw. The locking stone is a half-round piece of clear sapphire.

Balance: Guillaume nickel steel and brass 'integral' bimetallic balance with gold and platinum screws, the four quarter screws gold. Diam. of rim 18·2 mm, h. 1·82 mm.

Balance spring: Blued steel spiral spring of 15 complete turns with an overcoil and terminal curve of two turns, free sprung to a polished steel stud on the balance bridge and a polished steel collet.

Going-train counts:
Great wheel (barrel) 92 teeth
Centre pinion 14 leaves, wheel 96 teeth, 6 arms
Third pinion 12 leaves, wheel 75 teeth, 6 arms
Central fourth pinion 10 leaves, with another pinion of 12 driving a wheel fixed to the carriage of 120 teeth
The fixed ring with 100 internally cut teeth meshes with a fifth wheel on the carriage of 45
The wheel of 45 drives a pinion of 10 carrying a wheel of 80 driving the escape pinion of 8
The escape wheel has 15 teeth
Beats per hour: 18,000

The sixth wheel and pinion at the centre of the carriage make one turn per minute. In the patent specification the lower pivot passes through the lower carriage pivot.

Motion work: The steel minute wheel of 30 teeth is driven by another steel wheel of 30 teeth on an arbor passing through the hollow offset 'centre' pinion and retained friction tight by a nut and pin. The cannon pinion is a brass wheel also of 30 teeth. The minute pinion has 6 leaves and the hour wheel 72 teeth.

Rocking bar wheels: The large central wheel has 48 teeth, half bevelled. The small wheel for winding the barrel ratchet wheel, and the latter, have 17 and 60 teeth respectively. The hand-set wheel has 29 teeth. The steel wheel on the end of the pendant arbor has 31 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1948 (reg. no. CAI-1724).

Notes

1. J. A. Clemence (1843–1915), Liveryman of Clockmakers' Company in 1891; chairman of Carley and Clemence Ltd. For his obituary see *HJ*, February 1915, p. 80.
2. Andrew Taylor (1858–1909) patented amongst other things the annular tourbillon and a resilient escapement.

For an ébauche of this type of watch see cat. no. 187.

183 YEOMANS

Early 20th century

KARRUSEL *Plates 151b–e, 152a–b*

Signature: Stamped on the dial side of the front plate YEOMANS and '85222'. On the back plate '85222'.[1]

Case: Missing, but was open face.

Dial and hands: Flat enamel dial with sunk central portion, attached to the front plate by three feet and pins. The back marked 23 and K.

Gold minute and hour hands, blued steel sweep centre seconds hand.

Movement

Ebauche marks on the inside of the front plate B. Bonniksen's ébauche mark with the patent number, 21421. Fleur de lis mark between the S and F on the balance cock.

Front plate diam. 48·1 mm; front plate th. 4·20 mm (reduced to 2·60 mm); back plate diam. 45·6 mm; frame h. 10·0 mm.

Frame: Typical karrusel three-quarter plate construction with three turned pillars, the back plate retained by recessed blued steel screws. The massive front plate recessed under the dial, and with sinks turned on the other side for the offset centre wheel, the central fourth wheel and the lower pinion of the third arbor. The movement was positioned in its case by one large and two small pins in the edge of the front plate, and by two dog screws. All the brass parts gilded, except for two components of the carriage.

Going barrel and keyless work: The going barrel fitted with four-turn Geneva stop-work on the end, the finger-piece boss squared to the arbor and providing a pivot in the front plate. English rocking keyless work fitted on the front plate under the dial.

Going train: The centre arbor offset but turning once per hour. The motion work driven by a wheel mounted on the end of a rod fitted friction tight in the hollow centre arbor. The fourth arbor planted at the centre, the wheel meshing with another similar on the arbor of a third planted at the centre of the carriage. This final wheel meshing with the escape pinion. A large pinion on the third arbor meshes with teeth on the edge of the carriage and causes the latter to revolve about its axis. A stop is provided, once activated by a slide in the band of the case, operating on the teeth of the second fourth wheel. The polished steel pinions and arbors and the gilded brass wheels are all well made and finished.

Jewelling: The pivots of the third, fourth and the escapement arbors run in pierced jewels, those of the escapement upper and both balance staff bearings with endstones. The train jewels are made with curved faces against the pivot shoulders.

Carriage: Similar to that of cat. no. 185, signed 'Greenough & Sons', but arranged differently so that it revolves more quickly, once every 34 minutes. The escapement and balance are lodged in the frame of the carriage in an identical way to that of cat. no. 185. The carriage main plate pivots in a hole in the front plate and is held by a disc with three screws, on the dial side of the front plate. In cat. no. 185 the disc has teeth on its edge meshing with the leaves of the third pinion to drive the carriage, but in this example teeth on the edge of the carriage main plate itself mesh with the leaves of a separate pinion on the third arbor. These teeth are cut in a separate brass ring held by three screws to the underside of the carriage main plate. With the exception of this toothed ring and the carriage retaining disc all the brass parts are gilded, and several are punched with the number 22.

Escapement: Typical English ratchet-toothed lever escapement, with jewelled pallets, and a table roller having a ruby impulse pin with a slight flat facing the passing crescent.

Balance: Bimetallic two-armed balance with gold screws and quarter nuts. Diam. 17·4 mm, h. 1·6 mm.

Balance spring: Blued steel spiral spring of $17\frac{1}{2}$ tight coils, with an overcoil and terminal curve having a reverse curve, free sprung to a polished diamond-shaped steel stud on the balance cock, and a round brass collet.

Going-train counts:
Great wheel (going barrel) 90 teeth, round bottom
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 80 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
The second 'fourth' wheel in mesh with the first has 80 teeth and is carried on the arbor of the third 'fourth' wheel, in mesh with the escape pinion, having 68 teeth. Both these wheels have 5 arms.
Beats per hour: 18,000

The carriage has a ring of 136 teeth on its edge, in mesh with a pinion of 30 leaves on the third arbor, and makes one revolution in 34 minutes.

There is a stop working on the third wheel comprising a pivoted rocking piece with a brass flexible wire arm pinned into it.

Motion work:
First steel wheel carried on an arbor passing through the hollow centre pinion, 26 teeth
Minute wheel and cannon wheel both with 26 teeth
Hour wheel 72 teeth, 5 arms, minute pinion 6 leaves

Keyless work:
Pendant arbor wheel missing
Central rocking bar wheel 50 teeth
Intermediate hand-set wheel 26 teeth
Intermediate winding wheel 26 teeth
Barrel ratchet wheel 62 teeth

This watch was tested in the Kew Trials in 1902 (see table).

KEW OBSERVATORY Performance of the 52 watches which obtained the highest number of marks during the year 1902.

Watch deposited by	S. Yeomans, Coventry
Number of Watch	85222
Escapement, Balance spring, etc.	s.r., g.b., s.o., 'Karrusel'
Mean daily rate	
Pendant up	−1·5 secs
Pendant right	−1·4 secs
Pendant left	−1·2 secs
Dial up	+0·2 secs
Dial down	−0·4 secs
Mean variation of daily rate	+0·5 secs
Mean change of rate for 1°F	0·05 secs
Difference between extreme gaining and losing rates	4·0 secs
Marks awarded for	
Daily variation of rate (0–40)	30·4
Change of rate with change of position (0–40)	37·6
Temperature compensation (0–20)	16·5
Total marks (0–100)	84·5

Provenance: Ilbert Collection, purchased by Ilbert from Jauncey in 1935 (reg. no. CAI-1004).

Note

1. Samuel Yeomans of Coventry started business about 1880. A watch by him, no 196545, is in the National Maritime Museum, Greenwich (ref. no. Ch 285 A77-1(33)).

184 LOUIS DESOUTTER

1908

KARRUSEL *Plate 152c–e*

Signature: Stamped on the front plate under the dial in an oval cartouche 'L. DESOUTTER LONDON'.

Case: Open face silver case with the London hallmark for 1908 and the maker's mark 'F.T. London'. This was Frederick

Thoms. The pendant end bow with London hallmark. The pendant also with the maker's mark CH. The inner cover and back hinged to the middle with gold joints, the front bezel snapping onto the middle. The pendant hollow for the winding arbor with a steel bevel solid on one end and the winding button held with a nut on the other end which is squared. A separate push-piece and wide olivette are provided for operating the hand-set.

The front bezel, middle, inner cover and back are all punched with the number 2000. Case diam. 60·1 mm, h. 16·5 mm.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, fixed directly to the front plate by three feet and pins. The back of the dial signed 'WILLIS', and with the number 2000 scratched into the surface.

Blued steel hands.

Movement

Ebauche marks; the number 2000 is punched on the front plate under the dial, and the B. Bonniksen punch mark is applied to the inside of the front plate near a pillar in the usual way (see the watch by Greenough and Sons, cat. no. 185).

Front plate diam. 48·1 mm; back plate diam. 46·7 mm; front plate th. 3·26 mm (reduced to 1·86 mm); frame h. 10·0 mm over barrel.

For a description of the layout and construction of the movement see cat. no. 185 by Greenough and Sons, which this closely resembles.

The frame differs slightly from that of cat. no. 185 in that the back plate shows no sign of ever having been gilded and has been polished on the upper surface.

Jewels: Unlike cat. no. 185 there is a centre jewel in the top plate in a screwed setting.

Balance: Bimetallic two-armed balance with gold screws and quarter nuts, the balance exceptionally high at 2·2 mm. Diam. 16·8 mm, h. 2·2 mm.

Balance spring: Blued steel spiral spring of 14 turns and with an overcoil of two complete turns, free sprung to a polished diamond-shaped stud and a polished block-shaped steel collet.

Going-train counts:
Great wheel (going barrel) 90 teeth, round bottom to the teeth
Centre pinion 12 leaves, wheel 80 teeth, 5 arms
Third pinion 10 leaves, wheel 75 teeth, 5 arms
Fourth pinion 10 leaves, wheel 70 teeth, 5 arms
Escape pinion 7 leaves, wheel 15 teeth, 3 arms
The carriage is driven by a wheel of 70 teeth, meshing with the third pinion, and rotates once every 52·5 minutes.
The number of vibrations per hour of the balance must be $17{,}657\frac{1}{7}$.

Motion work:
Cannon pinion 16 leaves, minute pinion 8 leaves
Hour wheel 48 teeth, minute wheel 32 teeth

Keyless work:
Pendant arbor wheel 22 teeth
Central rocking bar wheel 56 teeth
Intermediate hand-set wheel 32 teeth
Intermediate winding wheel 26 teeth
Barrel ratchet 62 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Webster in 1931 (reg. no. CAI-952).

185 SAMUEL GREENOUGH AND SONS
1933

KARRUSEL *Plates 153a–f, 154a–e*

Signature: On the back plate 'Samuel Greenough and Sons, 45 Newport St. BOLTON 95301'. '(MAKERS TO THE ADMIRALTY.)' On the enamel dial, 'Makers to the Admiralty (S. Greenough and Sons) Bolton 9502'.

Case: Open face silver case with the London hallmark for 1933 and the maker's mark 'J.W. & Co. 95301' on the inner cover and the back. The glazed front bezel not hinged. The inner cover and back hinged to the middle. The pendant also with the London hallmarks. Diam. 56·5 mm, h. over glass 16·9 mm.

Dial and hands: Flat enamel dial with sunk subsidiary seconds, fixed directly to the front plate by three feet and pins.

White gold minute and hour, steel seconds hand.

Movement

Ebauche marks Bonniksen's mark on inside of the front plate. S.G. & S. on the front plate under the dial and 95301. The carriage brass parts marked 10.

Front plate diam. 48·4 mm; back plate diam. 45·7 mm; frame h. 9·1 mm; carriage diam. (max.) 20·90 mm; carriage h. 7·88 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate secured by blued steel screws. The movement secured in the case by a peg and two dog screws. The brass parts and those of the carriage gilded.

Barrel: Ungilded brass going barrel, with four-turn Geneva stop-work on the end opposite the cover. The great wheel teeth with rounded-tooth form. A sub plate supports the fourth and third pivots on the dial side, the jewels are rubbed in directly and are not in screwed settings.

Keyless work: English rocking bar keyless work, the hand setting operated by a push-piece passing through an olivette in the band of the case. The winding button screwed to the squared end of the winding arbor bearing in the pendant, and with an integral bevel wheel on the other end.

Going train: The great wheel teeth with round-bottom tooth form, the remainder of the train with square-bottom tooth form. The brass wheels ungilded, but burnished on both sides. The fourth wheel planted at the centre of the carriage with an extended pivot for the seconds hand. The latter driven by a wheel on its underside meshing with the third pinion, this wheel also having a round-bottom tooth form.

Karrusel: The escapement is lodged in the carriage frame and driven via the fourth wheel planted at the centre. The carriage itself makes a revolution in 52·5 minutes.

Escapement: English ratchet-tooth lever escapement with brass escape wheel, jewelled pallets and table roller.

Jewelling: The pivots of the third, fourth and escapement arbors in pierced jewels, the escapement and balance with endstones, the upper balance endstone a diamond.

Balance: Bimetallic two-armed balance, with gold screws and quarter nuts. Diam. 17·2 mm, h. 1·6 mm.

Balance spring: Blued steel spiral spring of 15 tight coils with incurved overcoil and terminal curve, circular brass collet.

Going-train counts:
Great wheel (barrel) 90 teeth
Centre pinion 12 leaves, wheel 80 teeth
Third pinion 10 leaves, wheel 75 teeth
Fourth pinion 10 leaves, wheel 70 teeth
Escape pinion 7 leaves, wheel 15 teeth
The wheel driving the carriage has 70 teeth
Beats per hour: 17,657$\frac{1}{7}$

Motion work:
Cannon pinion 16 leaves, minute pinion 8 leaves
Hour wheel 48 teeth, steel minute wheel 32 teeth
The cannon pinion slips directly on the centre arbor.

Keyless work:
Barrel ratchet wheel 62 teeth
Middle rocking bar wheel 56 teeth
Winding rocking bar wheel 26 teeth
Hand-set rocking bar wheel 32 teeth
Bevel wheel in the pendant 19 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1175).

186 ROBERT GARDNER, English

c. 1920

KARRUSEL EBAUCHE *Plate 155a–d*

Dial and hands: None.

Movement
Front plate diam. 47·0 mm; front plate th. 3·25 mm; back plate diam. 45·5 mm; overall th. 9·4 mm; carriage diam. 20·2 mm; carriage h. 6·8 mm.

Frame: Half plate layout with three turned pillars. The front plate not fully recessed so the exact layout of the wheels can only be inferred. One wheel seems to be missing, otherwise all are with the ébauche although all are not planted. The frame is of brass with the bridge for the carriage and its two supporting pillars of steel. Only a location peg is fitted to the ébauche; there is no provision for a dog screw. There is also no provision for the sub plates that would have been needed for the third wheel and the idle wheel that is missing. These sub plates would have been fitted to the front plate.

Going barrel: The going barrel is most unusual in an English watch as it follows American practice, with a barrel drum of steel and the great wheel running on the arbor. The great wheel has a boss 2·25 mm thick which is intended to bear the hook for the inner end of the mainspring. The arbor which is squared at both ends is integral with the Maltese cross finger of the five-turn stop-work. The square at one end carries the steel barrel and the square at the other the winding wheel. The overall height of the barrel is 5·1 mm, the internal diameter is 19·1 mm. The mainspring has not been fitted and is not with the ébauche but it would probably have been 3·5 mm in height.

Keyless work: English rocking bar keyless work. The hole for the push-piece not in the plate edge.

Going train: Great wheel teeth with round-bottom tooth form. Remainder of the teeth square bottomed. All wheels ungilded. The centre and third pinions separate from their arbors. No arbors pivoted except for the upper fourth. One wheel missing (see Train counts below).

Karrusel: The escapement is lodged in the carriage frame as is the fourth wheel and pinion. The carriage would make one revolution in sixty minutes and the fourth wheel within the carriage one revolution per minute and so was meant to carry the seconds hand. The outer wheel of ninety teeth that accepts the drive from the third pinion is a separate ring pressed over the body of the carriage. The carriage is recessed and carries two bridges in its lower half. This lower half has a boss which rotates in a large hole (3·60 mm diam.) in the front plate. There are two raised portions standing up proud of the edge of the carriage, one of which is broad and carries the wide end of the Y-shaped steel balance bridge. The other piece is narrow and supports the 'bottom' of the Y. The raised portions are stepped down to accommodate the thickness and width of the bridge which is not steady pinned in position. Instead there is a raised rim on its underside to centralise it. There is a single screw at the bottom end and that passes through the steel, but at the wide end the bridge is held down by two dog screws. (This is a most remarkable method of mounting a balance bridge.) Let into the wide end is a gold regulation scale which has been soldered in position.

Screwed to the bridge is the stud and the endpiece that carries the index. In the endpiece are three jewels; the normal pair for the balance pivot and another jewel hole that locates a pivot fixed to the carriage bridge. Although not used by other makers this seems a sound method likely to lead to a saving in height.

Escapement: An English ratchet-tooth lever escapement but the lever missing. The escape wheel brass.

Jewelling: It is not known how many jewels were intended but the escapement is jewelled, these already being in position in the carriage. There is also a jewel for the top fourth pivot, this being directly beneath the bottom balance jewels. Over the top balance jewels (in the balance bridge) is another jewel meant to work with a fixed pivot in the carriage bridge, a unique arrangement. This pivot not yet in the bridge.

Balance and spring: Not with the ébauche.

Going-train counts:
Barrel 90 teeth
Centre wheel 80 teeth, pinion 12 leaves, 6 crossings
Third wheel 80 teeth, pinion 12 leaves, 6 crossings
Fourth wheel 80 teeth, pinion 10 leaves, 6 crossings
Escape wheel 15 teeth, pinion 7 leaves

The idle wheel that should lie between the third wheel and fourth pinion is missing. The number of teeth would be unimportant.

Beats per hour: 18,000

Motion work:
Cannon pinion 16 leaves, minute pinion 8 leaves
Hour wheel missing but would have had 48 teeth, minute wheel 32 teeth

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1933 (reg. no. CAI-1464).

Note
This is obviously a prototype, no other calibres of this type are known.

187 ANDREW TAYLOR[1]

c. 1903

TAYLOR TOURBILLON EBAUCHE *Plate 155e–f*

Signature: None, but numbered 51621.

Dial and hands: Enamel canister dial, no hands. The dial, not inscribed, is marked with 0·4 second intervals as well as seconds. Since the watch would have been a single beat the centre seconds hand would register over these marks. On the back of the dial in the enamel is the number 21.

Movement
Ebauche marks on the front plate under the dial A.T. and the number 51621. Andrew Taylor of Coventry took out a patent on 5 September 1895, No. 16623, for a tourbillon mechanism. That fitted in this watch is similar, but not the same as that described in the patent. (see cat. no. 182 for a complete watch of this type.)

Front plate diam. 48·0 mm; back plate diam. 46·0 mm; front plate th. 4·0 mm; frame h. 11·3 mm.

Frame: Half plate construction with three turned pillars mounted on the massive front plate, the back plate secured by steel screws.

The carriage of the tourbillon pivoted between the front plate and a pierced brass bridge supported on two turned pillars.

Going barrel and keyless work: English rocking bar keyless work. The going barrel with five-turn Geneva stop-work, the back plate with a raised portion to accommodate the extra height of the barrel.

Going train: Conventional train with offset centre arbor as far as the fourth pinion which is planted at the centre. The fourth pinion missing. In a finished movement another pinion on the fourth arbor drives a toothed ring on the underside of the carriage. The teeth of a fifth wheel, mounted on the carriage about halfway in from the edge, mesh with those cut internally on a fixed ring concentric with the carriage centre. The fifth wheel teeth also mesh with and drive a pinion, planted at the centre of the carriage, on which is mounted a sixth wheel meshing with and driving the escape pinion. The total number of wheels in the going train, including the great wheel on the going barrel, is therefore seven and the total number of pinions is six. A conventional going train has four wheels and four pinions.

Jewelling: All the going train arbor pivots run in pierced jewels, from the offset centre arbor (the lower jewel not yet fitted) to the arbor of the wheel at the centre of the carriage, except the central fourth arbor lower pivot which runs in a brass bush. The escapement arbor pivots run in pierced jewels with endstones, the balance upper being a diamond. The sixth wheel jewels not in position.

Tourbillon: The brass carriage would turn once in ten minutes and is made up of a number of brass parts. The main plate is recessed on the upper side and has a fixed toothed ring fitted friction tight on the boss on the underside. A further sub frame on the underside with the carriage lower pivot and the lower bearings for the fifth, sixth and escape arbors, has three pillars passing through holes in the main plate. A bridge in the recess on the upper side of the main plate has holes fitted over the ends of the pillars and is retained by three screws going into threaded holes in the pillars. The main plate is therefore sandwiched between this bridge and the lower sub frame. In the bridge are lodged the upper bearings for the fifth, sixth and escape arbor pivots, these arbors passing through clearance holes in the main plate. The balance bridge fits onto three pillars on the edge of the upper surface of the main plate and carries the upper carriage pivot. The carriage is poised, metal having been removed from a slot in the underside of the main plate. The workmanship necessary to make the carriage and all its parts with a sufficient degree of truth, so that it can be entirely dismantled for cleaning, is of the highest possible order.

Escapement: Not yet in the ébauche but would be the Earnshaw type of spring detent escapement.

Going-train counts:
Great wheel (barrel) 92 teeth
Centre pinion 14 leaves, wheel 96 teeth, 6 arms
Third pinion 12 leaves, wheel 75 teeth, 6 arms
Centre fourth wheel missing
The fixed ring with 100 internally cut teeth is intended to mesh with a fifth wheel of 45 teeth in the carriage

The sixth wheel and pinion at the centre of the carriage makes one turn per minute. In the patent specification the lower pivot passes through the lower carriage pivot.

Motion work: The steel minute wheel of thirty teeth is driven by another steel wheel of thirty teeth on an arbor passing through the hollow offset centre pinion and retained friction tight by a nut and pin. The cannon pinion is missing.

Rocking bar wheels: The large central steel wheel has 48 teeth, half bevelled. The small wheel for winding the barrel ratchet wheel has 17 teeth and the barrel ratchet wheel itself has 60 teeth. The hand-set wheel has 29 teeth. The steel wheel on the end of the pendant arbor has 31 teeth.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1948 (reg. no. CAI-1462).

Note
1. Andrew Taylor (1858–1909) patented, among other things, the annular tourbillon and a resilient escapement. A watch containing this escapement and his tourbillon was auctioned at Christie's on 16 December 1987, lot 112.

188 ANDREW TAYLOR

1899

TAYLOR TOURBILLON EBAUCHE *Plate 156a–b*

Signature: None, but numbered 51607.

Dial and hands: None.

Movement

Ebauche marks on the front plate under the dial AT in a rectangle and the number 51607, also near the carriage bearing AT 71. On the inside of both the front and back plates AT 7571.

Front plate diam. 42·8 mm; back plate diam. 41·4 mm; front plate th. 3·1 mm; frame h. 9·45 mm.

Frame: Half plate construction with three turned pillars mounted on the front plate, the back plate secured by screws (missing). The tourbillon carriage pivoted between the front plate and a brass bridge supported by two turned pillars.

Going barrel and keyless work: The keyless work is unusual. On turning the button one way the watch is wound. The winding wheel is mounted on a steel sub frame which also carries an intermediate wheel. The sub frame has a slot in the winding wheel boss which fits over a stub pillar. If the button is turned the other way the winding and intermediate wheels move over on their sub plate until such time as a cut out in the sub plate comes opposite a pin fixed in the front plate. Not until then can the hand-setting pin be pressed in, thus rotating the sub plate until the intermediate wheel meshes with a second intermediate which is permanently in mesh with the motion wheel on the 'centre' wheel arbor. A steel cover plate holds down the sub frame. Conventional barrel with five-turn Geneva stop-work. Mainspring not fitted.

Going train: Train with offset 'centre' arbor. This wheel drives another; the third which has a steel wheel mounted on its pinion. This steel wheel acted on by a click which is presumably intended to prevent backward rotation of the train during hand setting. This would indicate that it was the intention to fit a detent escapement. This device has not been met with before. The third wheel drives a toothed ring mounted on the outside of the tourbillon carriage. In the carriage is an idle wheel which meshes with an internally cut gear fixed rigidly to the plate and concentric with the carriage. This idle wheel meshes with the pinion of what is effectively another third wheel planted so as to drive the fourth which is planted at the centre of the carriage. The fourth has an extended pivot to carry the seconds hand. None of the wheels past the first third wheel are with the ébauche.

Tourbillon: The brass carriage is intended to turn once in sixty minutes and is made up of a number of brass parts. The main plate is recessed on the upper side and has a fixed tooth ring fitted friction tight on the boss on the underside. A further sub frame on the underside with the carriage lower pivot and the lower bearings for the fifth, sixth and escape arbors has three pillars passing through holes in the main plate. A bridge in the recess on the upper side of the main plate has holes fitting over the ends of the pillars and is retained by three screws (missing) going into threaded holes in the pillars. The main plate is therefore sandwiched between this bridge and the lower sub frame. In the bridge are lodged the upper bearings for the fifth, sixth and escape arbor pivots, these arbors passing through clearance holes in the main plate. The balance bridge fits onto three pillars on the edge of the upper surface of the main plates and carries the upper carriage pivot.

Escapement: Not in the carriage, but was to be an Earnshaw spring detent.

Balance: Not in the carriage.

Going-train counts:
Great wheel (barrel) 92 teeth
Centre wheel 54 teeth, pinion 14 leaves, no crossings
Third wheel 40 teeth, pinion 18 leaves, no crossings

All other gears not in ébauche, except for the fixed ring of 100 internally cut teeth on the front plate and the carriage wheel of 120 teeth.

Provenance: Ilbert Collection; purchased by Ilbert from Malcolm Gardner in 1948 (reg. no. CAI-1463).

Note: For a complete watch of this general type see cat. no. 182.

189 MAKER UNKNOWN, but of Swiss origin

c. 1925

TOURBILLON EBAUCHE *Plate 156c–d*

Dial and hands: None.

Movement

Front plate diam. 44·5 mm; back plate diam. 44·5 mm; front plate th. 3·45 mm; frame h. 9·4 mm.

Frame: Half plate construction, with three turned pillars, material nickel silver. Third wheel top pivot in a cock, the lower third and carriage pivot (the fourth seconds pivot) carried by a basically circular sub plate held by two screws. The two steel pillars for the steel balance bridge are screwed to the front plate. The tourbillon carriage (not with the ébauche) is pivoted between the bottom circular plate and the steel bridge.

Going barrel and keyless work: Rocking bar keyless work, the barrel ratchet wheel and barrel not with the ébauche.

Jewelling: Only the top centre jewel screwed in, all the rest, the bottom centre jewel, the upper and lower third, and the carriage pivot jewels are rubbed in.

Going-train counts: No wheels with ébauche.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1482).

Note: Although the layout of the plates and the carriage bridge are in the English style this is undoubtedly a Swiss ébauche.

190 R. B. NORTH'S design, probably made by North & Sons,[1] English

c. 1905

TURBILLON EBAUCHE *Plate 152c–e*

Dial and hands: None.

Movement
Ebauche marks the number 13588. Also the carriage numbered 88.

Front plate diam. 45·3 mm; back plate diam. 43·5 mm; front plate th. 2·8 mm; frame overall h. 8·8 mm; carriage h. 7·0 mm.

Frame: Three-quarter plate layout with three pillars for the back plate, which is secured by screws (not with the ébauche). The carriage is 'flying', i.e. only supported at its bottom end. The edge of the carriage is gear cut and driven by the fourth pinion. The fixed fourth wheel lies beneath the carriage.

Going barrel and keyless work: The going barrel complete with arbor and four-turn Maltese cross stop-work is with the ébauche. Although the front plate is recessed to take rocking bar keyless work none is fitted.

Going train: Not fitted.

Tourbillon: The brass carriage was probably intended to rotate in six minutes. It consists of a main plate with its edge gear cut. It has a boss on its underside which passes through a clearance hole in the plate. Fixed to the plate by three screws is a steel disc with a central pivot which passes through a hole in the boss. The pivot is tapped to take a screw that retains the carriage.

Beneath the carriage plate is a bridge for the escape wheel and pallet. On the top of the bridge are two cocks, one for the escape wheel and pallets and the other for the balance. All of these parts are screwed and steady pinned to the plate.

In this design the balance is not mounted centrally in the carriage, being about 2·5 mm off centre.

Jewelling: There are no jewels fitted to the ébauche.

Escapement: Intended to be lever.

Balance and spring: No balance and spring with the ébauche.

Wheel counts:
Great wheel (barrel) 90 teeth
Carriage 120 teeth

Provenance: Gift of A. G. M. Clark in 1968 (reg. no. 1968, 4-3, 22).

Note

1. This design was patented by Robert Benson North, Patent No. 6737, in 1903. The patent covered both a four-minute and five-minute tourbillon.

Bibliography: Mercer 1981, pp. 212–213, pls 95, 96, pp. 424–5.

191 JOSEPH PRESTON, English

c. 1930

KARRUSEL EBAUCHE *Plate 157a–b*

Dial and hands: None.

Movement
Ebauche marks Joseph Preston's mark on inside of the front plate J.P.

Front plate diam. 46·2 mm; back plate diam. 44·3 mm; frame th. 9·0 mm; carriage diam. (max.) 20·25 mm; carriage h. 7·4 mm.

Frame: Three-quarter plate construction with three turned pillars, the back plate secured by screws (only one present). A sub plate supports the third and fourth pivots on the dial side, a cock supports the other pivot of the third wheel.

Barrel and keyless work: Going barrel missing. English rocking bar keyless work.

Going train: The central, third and fourth wheels with square-bottom tooth form. The fourth wheel planted at the centre of the carriage and to have an extended pivot for the seconds hand. The carriage driven by a wheel on its underside meshing with the third pinion, this wheel having a round-bottom tooth form.

Karrusel: The escapement was to be lodged in the carriage frame and driven via the fourth wheel planted at the centre but not yet fitted. The carriage intended to make a revolution in 52·5 minutes.

Going-train counts:
Great wheel (barrel) 90 teeth
Centre wheel 80 teeth, pinion 12 leaves, 6 arms
Third wheel 75 teeth, pinion 10 leaves, 6 arms
Fourth wheel 80 teeth, pinion 10 leaves, 6 arms
Escape wheel probably 15 teeth, pinion probably 8 leaves
The wheel on the carriage has 70 teeth.
Beats per hour: 17,657$\frac{1}{7}$

Motion work:
Cannon pinion 14 leaves, minute pinion 8 leaves
Hour wheel 48 teeth, minute wheel 28 teeth
The cannon pinion slips directly on the centre arbor.

Keyless work:
Barrel ratchet wheel 60 teeth
Middle rocking bar wheel 52 teeth
Winding rocking bar wheel 21 teeth
First hand-set rocking bar wheel 21 teeth
Second hand-set wheel 18 teeth

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1956 (reg. no. CAI-1076).

192 MAKER UNKNOWN

20th century

TOURBILLON EBAUCHE *Plate 157c–d*

Dial and hands: None.

Movement

Front plate diam. 55·0 mm; front plate th. 2·9 mm; back plate 54·5 mm; frame h. 11·0 mm.

Frame: Half plate construction with three turned pillars. The disposition of the wheel recesses in the front plate, where obviously the third wheel was to be positioned to drive the fourth pinion on the carriage, indicate that the ébauche was for a tourbillon.

Barrel and keyless work: No barrel and no pivot holes or recesses to take one. Rocking bar keyless work but only the bar and three wheels in position.

Provenance: Ilbert Collection, purchased by Ilbert from Malcolm Gardner in 1936 (reg. no. CAI-1481).

193 MAKER UNKNOWN, but probably Swiss 20th century

TOURBILLON EBAUCHE *Plate 157e–f*

Dial and hands: None, but dial was to be a canister dial as the ring for the dial is fitted to the front plate.

Movement

Front plate diam. 44·5 mm; front plate th. 3·5 mm; back plate diam. 42·5; frame h. 8·3 mm.

Frame: Nickel silver. Half plate layout. No cock fitted for the upper third pivot. A steel bridge fitted beneath the dial, this bridge 0·6 mm thick to take the lower third and the fourth pinion pivot jewels. The bridge screwed and steady pinned in position.

Provenance: Ilbert Collection, purchased by Ilbert from Gardner in 1948 (reg. no. CAI-1483).

Appendix

THE BALANCE AND SPRING

and various parts associated with precision timekeepers

I (cat. no 194) Balances with simple lamina not in the rim and not intended to correct for middle temperature error *page* 225

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Note

This Appendix contains all those pieces in the collection that are not associated with complete watches or movements, providing that they would have been meant for mechanisms that are applicable to this catalogue. Many of these parts are balances, and to make the Appendix of greater use mechanisms containing balances which are similar to those in the main catalogue have also been referred to and their catalogue numbers quoted. Few of these disassociated balances have springs, and by referring to complete specimens of a similar nature in the main catalogue it can be seen what sort of balance springs they would probably have had.

The National Maritime Museum were most helpful in providing copies of the results of chronometer trials. From 1845 onwards the type of balance in the chronometer is usually mentioned and this provided invaluable evidence as to the use and success of the various different types of balance.

All of the items in the Appendix (cat. nos 194–385) were purchased with the exception of the balances with registration numbers 1976, 2–2, 1–68 inclusive which were the generous gift of Dr Vaudrey Mercer, the author of the definitive works on Arnold, Dent and Frodsham (see Bibliography).

INTRODUCTION

The sensitivity of the verge and balance to changes in the torque supplied to it before the introduction of the balance spring is well illustrated by the fact that regulation was made by altering the set-up of the mainspring. In non-portable clocks with foliots or balances the driving force was sometimes altered to regulate the timekeeping but it was also possible to alter the inertia of the oscillator, the foliot or balance having a small weight on either side which could be moved along the arm. Regulation could also be effected by offsetting the suspension of the oscillator to a greater or lesser degree thus introducing a variable frictional restraint. To this end the cord from which the oscillator was suspended was located in one of a series of notches so that controlled movements could be made. These methods were not applicable to portable timekeepers except for altering the set-up of the main spring. A ratchet controlled by a spring was fitted to the ratchet wheel on the barrel arbor and had an end accessible to the owner. Setting up would make the watch gain and vice-versa. This practice doubtless provided plenty of work for watchmakers since if the owner set the mainspring up too much the result would be a broken gut fusee line. By 1640 the ratchet and wheel was beginning to be replaced by a worm and wheel assembly. This had the advantage of a 'micrometer' action, and could also be turned equally easily in either direction. However, after the introduction of the balance spring it was no longer necessary for the owner to regulate his watch by forever fiddling about with the mainspring set-up. The worm set-up then moved inside the movement, being sandwiched between the barrel and the pillar plate, but was there only for the convenience of the watchmaker so that he could set the mainspring up the correct amount when making his initial adjustments.

As already mentioned in the Historical Introduction, for portable timekeepers the key invention that led to accurate timekeepers was that of the balance spring. The development of the balance spring probably stemmed from the investigations into the properties of springs by Dr Hooke which resulted in his law, best summed up in the phrase *utensio sio vis* – 'as the tension is so is the force'. This means that if a spring is tensioned or deformed from the relaxed condition the force it exerts is in direct proportion to the amount of the deformation. If a certain deforming force causes a given deformation, then double the deforming force will produce exactly twice the deformation and half the deforming force will produce exactly half the deformation. This is true within a certain range of forces which do not overstrain the spring and thus cause a permanent deformation or a breakage. Hooke realised that by using a spring the greater the amplitude of the balance, the greater the spring would be tensioned and the greater restoring force it would exert. Whatever the amplitude of swing the time to perform it should thus be the same. This property is known as 'isochronism'. Hooke tried to devise some way of attaching a spring to a watch balance and collaborated with Thomas Tompion to this end, but does not appear to have succeeded, and the design of a steel spring bent into a spiral is credited to Christian Huyghens. The addition of a controlling spring in portable timekeepers produced a revolution similar to that produced by the introduction of the pendulum in clocks, and the balance spring soon came into general use.

There was little further development however until John Harrison turned his attention to marine timekeepers. The first marine timekeeper he made has two bar balances interconnected by large coiled helical springs working in tension.[1] It was perhaps the first balance-controlled machine to go with sufficient accuracy for one of the main errors associated with the balance spring to be detected, namely the effect of changes in temperature on its elastic properties. Rising temperature weakens the spring and causes a timekeeper to run progressively slower; falling temperature has the opposite effect as the balance spring becomes stiffer. There are also lesser effects caused by the changes in dimensions of both spring and balance. To correct the error Harrison used a grid-iron system. Steel and brass rods were arranged so that the free end of the final rod had the largest possible movement in relation to the fixed end. This movement was used to operate a variable tensioning device, via a system of levers, acting on the fixed ends of the balance springs.

Harrison's second marine timekeeper was similar to the first but with one important addition. It was already known that variations in the balance amplitude almost always produced variations in the rate of going. In other words, the balance and spring system, even when compensated for changes in temperature, is not isochronous. Since this appeared to be an inherent fault, Harrison's method of eliminating it was to try to keep the amplitude as constant as possible, and to this end introduced a train remontoire.

Harrison's third marine timekeeper, H3, was similar in principle to the second but was overtaken by the fourth, a radically different mechanism. This and H3 contained the first compensation curbs. A compensation curb is composed of two thin strips of different metals – usually brass and steel – which are riveted or fused together. Changes in temperature cause one strip to expand or contract more than the other, due to their different coefficients of linear expansion. These relative movements result in the strip curving more or less. One end of the strip is fixed, the other carries a pin or pins acting on the balance spring. As the end of this strip moves, the effective length of the spring changes. The disadvantages of such an arrangement, especially if mean time adjustments are made by changing the effective length of the spring, is that the isochronal properties of the spring may, and probably will, be affected adversely.

Pierre Le Roy and the 'perfect' timekeeper

The next and most significant contribution was that of the Frenchman Pierre Le Roy (1717–85) who carried out a series of experiments with a plain balance and spiral spring. He discovered that if the length of the spiral spring was varied, then at a particular length the system would be almost isochronous over a certain range of amplitudes. To bring the timepiece to time, weight was added to, or subtracted from, the balance. This discovery led him to the conclusion that any thermal compensation for changes in the elastic properties of the balance spring which acted on the spring itself would upset the careful adjustments for isochronism. He therefore proposed that the compensation should be incorporated in the balance itself.

Compensation is accomplished by the use of a pair of 'alcohol in glass' thermometers, each having a thread of mercury beyond the alcohol. These thermometers are mounted on the balance in such a way that a change in temperature causes the alcohol in each bulb to expand or contract, moving the mercury towards or away from the centre of the balance. The resultant change in the inertia of the balance could, after careful adjustment, be made to provide a nearly perfect compensation.

Slightly earlier, in 1761, Le Roy had devised a bimetallic balance similar to that to be developed by Earnshaw. However, he apparently discarded it in favour of the mercury and alcohol version.[2]

John Arnold's balance

Knowledge of Le Roy's discoveries does not appear to have reached England for some time after their publication in Paris. Towards the end of his life, John Harrison proposed independently that thermal compensation should be incorporated in the balance of a timekeeper though he did not, as far as is known, make an example and nor did his son and close collaborator, William Harrison.

John Arnold's earliest chronometer dates from about 1769. It differed in almost all important aspects from Harrison's, simplicity being the keynote. Arnold concentrated a great deal of effort on the balance and spring system. His earliest machines, both marine and pocket, have a plain brass balance, a plain spiral balance spring of steel and a compensation curb which like Harrison's acted on the balance spring.

Arnold then began experiments to incorporate compensation into the balance itself.[3] At first sight this would seem to be more difficult to make and adjust. Thomas Mudge, who used an adjustable compensation system operated by two bimetallic strips, certainly thought so. The advantage of Mudge's complicated system is that small corrections to the amount of compensation can be made without stopping or upsetting the balance.[4] Arnold was not deterred by these difficulties which turned out to be more imaginary than real. Between about 1775 and 1790 he invented and developed a series of balances incorporating compensation operated by various metallic arrangements. The bimetallic parts were almost invariably made as separate units and then screwed to the balance. The objection to this is that the balance is not perfectly matched in all its parts, tends to lack rigidity and is more difficult to make well than the type of bimetallic balance devised by Thomas Earnshaw.

Thomas Earnshaw's balance

In Earnshaw's balance the steel part of the bimetallic rim sections is one with the steel cross bar of the balance. Initially the rim is made by turning a steel disc true in the lathe, and then fusing a ring of brass on the outside. After hammering or rolling the brass to compress and work harden it, the rim can be turned perfectly true before filling the arms. Thus there is the minimum of finishing to the rim before it is slit. Earnshaw then cut short segments from a ring of brass as weights and fitted one near each free end of the balance rims. These weights are carried towards the balance centre in heat and away from it in cold, and can be moved towards or away from the free ends of the rim to alter the amount of compensation.

The helical balance spring and terminal curves

At about the same time that John Arnold decided to abandon the compensation curb in favour of the compensation balance, he also decided to abandon the spiral spring. His objection to the spiral spring is recorded in the evidence he gave before a select committee of the House of Commons set up to decide whether Thomas Mudge deserved a reward from the Board of Longitude for his timekeepers. Arnold was asked, 'What objections are there against the common spiral spring?' He replied, 'that it is never a spiral, but when it is at rest; for the instant it begins to move, it assumes a figure that is not a perfect spiral, but when the spring opens and closes by contrary vibrations'. The underlying principle is that this distortion of its shape, by virtue of the fact that the outer end is rigidly fixed causing the spring to work on one side only, destroys its isochronal properties. Le Roy, as we have seen, was also aware of this but had discovered that under certain conditions and over a strictly limited range, a spiral spring could be made isochronous.

John Arnold decided to try a new approach and developed a helical or 'cylindrical' spring, not used in tension in Harrison's way, but in torsion. The initial results must have been considerably worse than those obtained with a spiral spring. A helical spring attached at one end to a collet on the balance staff, and at the other to some fixed point, will go through the most alarming series of wobbles and contortions as the balance moves and in the process its isochronal properties will be largely destroyed. However Arnold later hit on the plan of bending the end coil inwards in gentle curves towards the centre, and by manipulation of these was able to make the spring retain a stable cylindrical shape, it simply changed in diameter as the balance vibrated. He obtained a patent for a helical spring in 1775 and for terminal curves in 1782. A mathematical analysis of isochronous terminal curves was developed and published in 1861 in Paris, by Edouard Philips, a French mathematician and mining engineer.[5] Further work leading to directly applicable practical results was published by Lossier, Caspari, Grossman, Sautebin and others (see Bibliography).

Escapement errors and the instability of the bimetallic balance

A perfectly isochronous balance and spring system will not remain so when connected to even the most perfect of detached escapements. The reasons have been summed up in a law postulated by Sir George Airy, 'Acceleration before the line of centres will produce a shortening of the periodical time, acceleration after the line of centre a lengthening. Deceleration before and after the line of centres will have the opposite effect.' These effects become progressively greater as the amplitude of the balance diminishes and are known as escapement errors. Retardation will occur if the balance has to effect unlocking and impulse will normally also give a loss.

By the very nature of its construction the cut bimetallic balance has an inherent weakness. The rim sections must be sufficiently flexible to move with changes in temperature. As the amplitude of swing increases, the centrifugal forces acting on the rim sections also increase and the rims move outwards slightly. The effect is progressive and causes an increase in the time of vibration as the amplitude increases.

Escapement and centrifugal errors can be made to cancel each other out to some extent, or at least their effect can be made the same by careful adjustment so that they take over from each other and the result is a slight loss over the whole range of amplitudes. The timepiece can then be brought to time by moving the timing screws on the balance. Any residual error or any other gradual and progressive error that varies with the balance amplitude can also be reduced or eliminated by careful adjustment to the terminal curves to make the balance spring non-isochronous in the opposing sense. When the balance rim is cut, the degree to which the rims will deflect will of course depend upon the particular design and the materials used.

Victor Kullberg[6] did some serious work on the problem of centrifugal errors which he reported in *H.J.*[7] His experiments proved that the effect was greater than had been suspected. He used a chronometer with an isochronous spring kept at a uniform temperature and fitted balances with rims of different thicknesses to it. With the thinnest rims the mean daily rates in the long and short arcs differed by no less than 30 seconds. He suggested, as a result, that the rims of balances should be made deeper. This would not affect their compensation performance but would reduce the centrifugal error. However, makers were in the habit of using this error to help overcome the long-term changes in rate that would otherwise occur due to the deterioration of the oil. Whether this balancing of errors is a good thing is doubtful for centrifugal distortion of the rims of the balance leads to instability due to fatigue of the rims. The rims are not the best of assemblies from the point of view of their behaviour as springs, how good they are being partly dependent on the method of hardening the brass after it had been softened by fusing it to the steel. In a lecture given in April 1907 T. D. Wright mentioned three different methods then in use.[8] In the Omega factory the brass was hardened by passing it between rollers, in the Favres-Jacot factory by mechanical hammering and at Rotherham's factory by being pressed through a tapered hole in hard steel. There is little doubt that the last method was the most satisfactory, but it was probably also the least used.

Both Arnold and Earnshaw achieved considerable skill in detecting the various errors and balancing them, even making allowance for such long-term effects as the thickening of the oil in a timekeeper, so that the rate could remain constant.

Balance spring materials and their treatment

The earliest balance springs were probably made of steel wire either drawn or rolled to the required section with frequent annealing to prevent the material from becoming too brittle. They were left in a work-hardened state and not hardened and tempered. Later, ways were found to harden and temper them and John Arnold hardened and tempered his springs. Such springs are more elastic and retain their elasticity with time but are more difficult to make because the frequent annealing – heating to red heat and then cooling – during the preparation of the wire can cause the material to become deficient in carbon and it will then not harden properly. There is also an initial acceleration in the rate of a chronometer fitted with one of these springs, until the crystal structure has settled down, after which they are remarkably stable for some decades at least.

Earnshaw made his springs in the old way for no apparent reason other than that it was different from the way Arnold made them. His chronometers tended to run slower with time as a result, so he left the balances fast in the short arcs thus giving the compensating error for the loss of arc due to thickening of the oil. Unfortunately carbon steel, whether hardened and tempered or not, is subject both to rusting and magnetism. Arnold made some of his springs of a special alloy of gold[9] for a number of years and other makers have tried this from time to time, but it appears to suffer from the same disadvantage as unhardened steel, and in addition requires more thermal compensation.

With the advent of iron ships and the attendant problem of magnetism, John Roger Arnold and Edward John Dent did experiments with glass springs and found they required less thermal compensation than steel. These proved remarkably durable and withstood tests of a most violent nature. However glass, being a supercooled liquid, is an unstable material and tends to shrink and harden with time, and sometimes to form crystals, so that even apart from the difficulty of working, it proved unsuitable for balance springs.

Auxiliary compensation and middle temperature error

Towards the middle of the first quarter of the nineteenth century the accuracy of chronometers was such that a new error in their going was detected. It is not entirely clear to whom credit should be given for the discovery but it may well have been J. G. Ulrich. This error is caused by the compensation produced by the usual form of bimetallic balance not matching the variations in the elasticity of the spring with temperature. It can be proved mathematically that the changes in elasticity of a carbon steel spring, and of most other spring materials, varies in a non-linear way with temperature. An increasing temperature does not produce a proportionate increase in the elastic properties of the spring; the effect becomes progressively greater. On the other hand the net compensating effect produced by an ordinary bimetallic balance of Earnshaw type is almost exactly proportional to a change in temperature. A chronometer fitted with this balance and spring system, if carefully adjusted to keep time at two extremes, say 4°C and 36°C, will gain about 3 seconds per day at 20°C. If it is however brought to time at 20°C it will lose about 3 seconds per day at the extremes. This error is called the middle temperature error and however carefully a simple compensation balance is adjusted, it remains.[10]

Throughout the rest of the nineteenth century a vast amount of ingenuity was expended by chronometer makers to devise a modified form of balance in which the compensation weights would be carried inwards more in heat than outwards in cold, in other words to make a balance with non-linear compensation to match the non-linearity of the elastic properties of the balance spring. These are divided into two categories known as discontinuous and continuous. The former are more common and come into action at a predetermined temperature; the latter are always in action.

The palladium spring

Around 1880, C. A. Paillard (1840–95) developed an alloy of palladium which could be used for balance springs.[11] It proved to have a smaller middle temperature error than steel; about half. Once it came into general use there was a move away from continually acting compensation balances, for the results with a palladium spring and a simple discontinuous balance were comparable. The reduction in the middle temperature error meant that there was really no justification for using anything other than the simple discontinuous balance.

The palladium spring requires slightly more compensation than a steel spring and is heavier and softer but these disadvantages were outweighed by other considerations. In addition to that mentioned it had two further merits; it was not affected by magnetism and did not suffer from the same degree of acceleration as a steel spring during its first year of use.

From 1895 to 1914 chronometers with the combination of a palladium spring and a balance with auxiliaries dominated the field in England and took first place in the Admiralty trials every year.

The palladium spring was incorporated into 11 of the 26 best watches in Class A in the Geneva watch trials of 1883. Paillard himself had adjusted two of these eleven watches. The winning watch had a compensation error of ±0·066 secs/degree centigrade and was manufactured by Henri Capt and adjusted by L. Bornand. All the watches had lever escapements except one of the two adjusted by Paillard which had a chronometer escapement and a cylindrical palladium spring. In 1887, 22 out of 23 watches in the French trials had palladium springs. Heavy as palladium was (a density of 11 as opposed to 7·8 for steel) it was still possible to use it for making a cylindrical spring for a pocket watch without the adjacent coils touching in use. Alloys of palladium varied considerably in their constituents, from 45 to 75 parts palladium, 15 to 30 parts copper, 20 to 25 parts silver with sometimes the addition of small quantities of iron, gold or platinum.

Dr C. E. Guillaume[12]

The ultimate solution to the problem of the middle temperature error when using a steel balance spring and balance combination was discovered by a Swiss metallurgist and metrologist, Dr Charles Edouard Guillaume, who worked for many years as the head of the Bureau International des Poids et Mesures, at Sèvres in France. During his work in the late 1890s on the range of alloys of nickel and steel, he discovered one, later known as Invar, whose physical dimensions are virtually unaffected by the normal daily changes in temperature. Invar was first used for making precision scales and rules, for which purpose it was developed, and subsequently for the pendulum rods of accurate clocks. The alloy consists of just under 36% nickel, 0·4% manganese, 0.1% carbon with the remainder iron. Guillaume explained that the manganese and carbon could not be removed from the alloy and caused excessive difficulty when it needed to be forged and cold worked.

In the same family of alloys Dr Guillaume discovered that one containing 44% nickel had non-linear properties. He predicted mathematically that a bimetallic balance of Earnshaw type in which the steel parts were made of an alloy of this composition would eliminate middle temperature error when used with a carbon steel spring. The calculations were made in the spring of 1899.[13] Initial practical work was undertaken by James Vaucher of

Travers, Paul D. Nardin of Le Locle and Paul Ditisheim of La Chaux-de-Fonds. The first results attested by the Observatory of Neuchâtel were very encouraging and were announced at an International Chronometry Congress in 1900. The new type of balance, known as the 'integral' was found to have other advantages. It was less subject to rusting and magnetism, and because of the lower coefficient of expansion of the steel component compared with ordinary steel, the rim sections could be made shorter and more rigid for the same amount of compensation. This considerably reduced the errors produced by centrifugal forces. This balance subsequently held undisputed sway for the highest precision mechanical work until the Hamilton balance was developed.[14]

The 'self compensating' balance spring

One of the difficulties of working Invar is that, as already mentioned, the presence of impurities makes it difficult to form. The Societé de Commentry-Furchambault et Decazeville, a steel supplier in France working for Dr Guillaume, had tried to find alloys similar to Invar but easier to work.[14] They first increased the proportion of manganese, and then added chromium, copper and carbon. In determining the properties of the various alloys produced, a new line of approach suggested itself to Dr Guillaume. He began to search for a balance spring material whose elasticity would not vary with temperature. After some initial difficulty an alloy that he called *Elinvar*, a contraction of 'élasticité invariable' was discovered. Tests carried out in 1913 gave encouraging results. No further work was carried out until 1919 owing to the First World War. Dr Guillaume's ultimate objective was a balance spring alloy with a remaining slight response to temperature change so that when used with a plain brass balance it could compensate for both its own and for the latter's change in dimensions. This proved to be difficult to achieve because when ingots of Elinvar alloys were cast they were found not to be homogeneous, so that wire made from different parts of the ingot had different properties. Paul Ditisheim found a solution to this problem by using a brass balance to which he fixed short bimetallic 'affixes'. These could then be adjusted to give whatever residual compensation was required. Its thermo-elastic coefficient can not only be low but also can be either positive or negative according to the composition, mechanical treatment and heat treatment. The composition is generally 35 % nickel, 12 % chromium and the balance iron. Small additions are made of tungsten, carbon and silicon.

The elastic limit can only be raised by drawing and rolling and then to an extent a sixth less than that of spring steel. The spring is heated to set it into its final form. It is not surprising then that Elinvar springs are not so stable, and are softer and easier to damage.[14] They are therefore not really suitable for high quality timekeepers.

Since 1930 a number of superior alloys have been developed, their trade names being Ni-Span C, Nivarox and Isoval. Alloys of this type will contain roughly 40 % nickel, 5·5 % chromium with the addition of small percentages of titanium and aluminium as precipitation hardening elements. The remainder of the alloy will be iron with small additions of silicon and manganese.

In practice the temperature errors of these springs varies with the quality. First quality springs have errors of approximately ±0·3 seconds/day per degree centigrade and second quality ±2 seconds per day per degree centigrade.

Balance with affixes for use with springs with low thermo-elastic coefficients

Some attempts were made to correct for the last remaining errors of top grade 'self-compensating' springs by fitting affixes to uncut balances. Balances of the Ditisheim type are cat. nos 146, 290, 291 and 292. Cat. no 291 is complete with its spring. Cat. no. 146 is in a complete watch but there is no separate illustration of it. Paul Ditisheim was a superb adjuster of watches and in his hands the results with the affix uncut balance set new records at most of the world's observatories.[15]

This success does not appear to have been repeated by others and the Guillaume balance once invented was the balance *par excellence*. Only recently have springs of the self-compensation variety been produced which are so superior that they are competitors to the steel spring-Guillaume balance combination.

Modern springs with ovalising balances

The Hamilton Watch Company of the USA is to be credited with being the first to produce such superlative Ni-Span C spring material that it fully justified the use of a balance that could be adjusted so as to get rid of the major part of the small remaining temperature error. Hamiltons chose to use an ovalising balance for this purpose.[16] The first such balance was invented by Charles Volet who was a colleague of Charles Edouard Guillaume. He collaborated with Paul Ditisheim in this invention. Gould mentions that Ditisheim had discussed the balance with him.[17] The Volet balance is bimetallic but not cut, instead the bar or arm is made of brass and the rim of steel. When the temperature changes the balance is thus caused to become oval. By grouping the screws nearer to or further away from the arm the degree of compensation can be adjusted.

Another type of ovalising balance was the Straumann. This is unique inasmuch as it is monometallic. It was developed by M. R. Straumann,[18] and the same alteration from circular to elliptical is produced, but by simpler means.

Certain metal crystals have different coefficients of expansion in different directions, e.g. zinc. If the fracture of a cast sheet of zinc alloy containing a certain percentage of cadmium or copper is examined microscopically, it will show a crystalline structure, crystals jumbled up without an orderly arrangement; the expansion on heating this would be the same in all directions. If this sheet is rolled the crystals will rearrange more or less longitudinally in the direction of rolling, and the sheet will be found to have a greater coefficient of expansion along the line of rolling. The difference will be greater if pure zinc is used, which for various reasons is impracticable. One of the special alloys of the Straumann balance has a coefficient of expansion in the direction of rolling of 0·000030 and at right angles 0·000008. The balances are cut out of the sheet so that the cross bar lies in the direction of rolling, consequently it lengthens with the application of heat and so reduces the transverse diameter. The rim is drilled and tapped with twelve holes equally disposed around the balance for the reception of compensating screws. A change of position of a pair of screws from the end of the bar to the middle of the rim will counteract the effect of a change of rate of one second per degree C per 24 hours, which is the normal error of an Elinvar spring. It was patented in 1919 by the Thommen Factories of Waldenburg and called the 'anisotrophic' balance.

The Hamilton balance, although the same in principle, is different in detail, the arm being of Invar and the rim of stainless steel. The two are joined together by hard soldering. Again the balance can compensate for a spring with a slightly negative or slightly positive temperature coefficient merely by distribution of the screws around the rim. A balance of this type is cat. no. 292.

An experimental balance by Mercer is a further example. This has an aluminium bar with a steel rim and is reminiscent of early balances inasmuch as it is screwed together. However, up-to-date techniques are used since the screwing is reinforced with a cement. Three screws are used at each end of the cross bar which is lapped over the rim top. It proved unreliable in action.

Record of the types of balance used in the chronometers gaining top marks in the Greenwich Trials from 1845 to 1914

Balances marked with an asterisk are continuous in their correction for middle temperature error.

Poole's Auxiliary
1854, 1855, 1856, 1861, 1876

unnamed auxiliary
1853, 1858, 1859, 1865, 1866, 1867, 1874, 1875, 1894

*Loseby's Mercurial**
1845, 1846, 1850, 1851, 1852

*Hartnup**
1857

*Kullberg's Flat Rim**
1862, 1864, 1872, 1873

Fletcher's Auxiliary
1863, 1869

*Uhrig's Auxiliary**
1886, 1887, 1890, 1892

*Frodsham's Reversed**
1871

Isaac's
1877, 1893

ordinary with slight additions
1860, 1868, 1878, 1879

no information available
1847, 1848, 1849, 1870, 1880, 1881, 1882, 1883, 1885

Balances with palladium springs
With auxiliary
1888, 1889, 1896, 1897, 1899, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1907, 1908, 1909, 1910, 1911, 1912, 1913, 1914

Without auxiliary
1895, 1898

Notes

1. Gould 1923, p. 44.
2. Gould 1923, p. 88.
3. Mercer 1972, pp. 46, 55–57.
4. R. Good, 'Mudge's First Marine Timekeeper', Monograph No. 3, *A.H.*, n.d.
5. M. Phillips, 'The Pendulum Spring', *H.J.*, October 1863, pp. 13, 14.
6. Victor Kullberg, 'Balances', *H.J.*, March 1863, p. 80; 'Balances', *H.J.*, April 1863, p. 93; 'Balances', *H.J.*, January 1875, pp. 66–8; 'Obituary' *H.J.* August 1890, p. 185–7.
7. Victor Kullberg, 'Centrifugal Force and Isochronism', *H.J.*, September 1887, pp. 6, 7.
8. Reported in *H.J.*, May 1907.
9. 'Gold Springs', *H.J.*, May 1863, pp. 104–5.
10. Vaudrey Mercer, 'The Penningtons and Their Balances', *A.H.*, Spring 1981, pp. 514–22, and *A.H.*, September 1981, p. 44. Gnomon, 'Auxiliary Compensation', *H.J.*, February 1862, p. 8. 'Auxiliary Balance by M. F. Dent', *H.J.*, February 1863, p. 73.
11. Edward Rigg, 'Compensation', *H.J.*, June 1879, pp. 119, 128, 144, and *H.J.*, May 1879, p. 115.
12. Dr Charles Edouard Guillaume, 'Obituary', *H.J.*, August 1938, p. 9. 'Invar Balances', *H.J.*, August 1906, pp. 186, 187. 'The Compensation Balance', *H.J.*, May 1907, pp. 137–44. Robert Milne, 'Invar Balances', *H.J.*, July 1906, p. 175.
13. *Journal Suisse d'Horlogerie*, 1899.
14. 'Invar and Related Nickel Steels' *H.J.*, June 1919, pp. 115–18. E. W. Birch, 'Invar and Related Alloys', *H.J.*,

September, pp. 13, 14. C. E. Guillaume, 'The Middle Temperature Error', *H.J.*, July 1914, pp. 169–74. 'Nickel Steel Hairsprings', *H.J.* July 1903, p. 154; David S. Torrens, 'Notes on Elinvar', *H.J.*, January 1939, p. 26–8.

15. Chamberlain 1941, p. 65.
16. David Harries, 'American Chronometers', *H.J.*, May 1973, pp. 11–23.
17. Gould 1923, p. 202, f.n.
18. A technician and director of the Thommen watch factory of Waldenburg.
19. E. W. Birch, 'The Properties of Hairsprings', *The Practical Watch and Clockmaker*, August 1928, p. 317, September 1928, p. 387, 388, October 1928, pp. 437, 438, November 1928, pp. 493, 494, December 1928, pp. 545, 546, February 1929, pp. 654, 655, March 1929, pp. 74, 75, 76.

I (cat. no. 194)

BALANCES WITH SIMPLE LAMINA NOT IN THE RIM AND NOT INTENDED TO CORRECT FOR MIDDLE TEMPERATURE ERROR

There are three sub types represented in this section: the 'Double T', the 'Double S' and the 'Double L', which is a special form of the Double T. These types of balance were the first in which the correction for temperature errors was applied to the balance instead of to its spring. However in this group of early compensation balances the compensation device is not incorporated into the rim.

John Arnold started to make his first compensation balance in about 1774. In this he used his idea of a coiled curb but instead of this acting on the spring its inner end was attached to the balance close to the staff. It then coiled around the staff for a few turns, the outer end being attached to the end of a slotted bar which in turn operated two weights. These weights moved in and out as the bimetal coil responded to changes of temperature. This device was patented in 1775; the patent number was 1113.[1] There is no example of this type of compensation balance in the Collection nor, in fact, does any appear to have survived.

The next balance developed by Arnold was the Double T. Here the coiled bimetal strip is replaced by two straight lamina pivoted between the rims. These lamina carry steel rods which terminate in weights. The faults in this type of balance are first that the slop of the pivots in their holes leads to uncertain action, and second that as the lamina expand they can distort the balance.

The first of these balances was fitted to the famous chronometer No. 36.[2] According to Rees about twenty chronometers containing this type of balance were made between 1778 and 1780.

The third type of balance, the Double S, was developed to overcome the problems of the Double T. Here the length of the lamina is increased by making it S-shaped and its outer end is rigidly fixed to a flat collet on the balance. Its inner end carries the rods on which are mounted the compensation weights.

The 'Double L' balance is a special form of the 'Double T' but does not have its disadvantages. Only one side of the cross of the T is present and is fixed rigidly to the ends of the balance arms of which there are two. There is no rim to the balance which must have complicated poising. Another form of this balance is shown in Rees, it has four arms each with its bimetal strip (Pl. XXIX, fig. 9).

Notes

1. Rees's *Cyclopaedia Clocks Watches and Chronometers* London 1820 contains a valuable section '*Compensation*', pp. 143–156. On p. 149 Rees states that Arnold used this balance in ten to twelve chronometers from 1775–78.
2. Gould 1923, pp. 110, 111.

I Balances with simple lamina not in the rim and not intended to correct for middle temperature error

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
8			Double S	trammel wires	1780	John Arnold	CAI-301
126			Double S		*c.* 1797	Richard Pendleton	CAI-1118
119		82, 83	Double S	Patented 1782	1786	Josiah Emery	CAI-1645
124			Double S		*c.* 1794	Josiah Emery	CAI-510
4		4	Double T fitted later	improved version; invented 1778	*c.* 1773	John Arnold	1974, 9–12, 1
6		6	Double T	improved version	*c.* 1775	John Arnold	CAI-1839
7			Double T	trammel wires; 1st example	*c.* 1775	John Arnold	CAI-2067
	194	158	Double T	incomplete diam. 40, h. 3·5			1976, 2–2, 1
39			Double L or cruciform	really a special form of the double T; invented *c.* 1797	1796	Arnold & Son	CAI-1948
5			early Z with short integral T		1780	John Arnold	CAI-1838

II (cat. nos 195–216)

BALANCES WITH SIMPLE LAMINA AS THE RIM

Seven different types are represented in this section, the Arnold OZ, Z, YZ, Z and O, the Earnshaw two-arm, the Earnshaw type two-arm, three-arm and four-arm and the aerodynamic balances which are in this case modified Earnshaw two-arm balances.

The Arnold balances (the story continued)

The OZ balance consists of an ordinary three-arm steel balance to which are attached two bimetal rims. Small brackets join these rims to the balance being diametrically disposed. The free end of each rim is threaded and carries a cylindrical weight which is screwed further on or off to adjust the degree of compensation. This balance was widely used by Arnold from 1781 and continued in use until 1791.

The Z balance was very like the OZ except that the steel balance is omitted and a simple bar carries the bimetal rims. This became the standard type and was used until as late as 1818.

The YZ balance is simply a three-arm version of the Z balance.

Arnold 'Z+O' (cat. no. 196)

Typical Z balance with additionally a second rim secured by screws and positioned by two blocks on the balance arm. This rim carries three segment weights for poising purposes.

The 'Earnshaw' balance

Although called the 'Earnshaw' balance this type of balance was not invented by Earnshaw, nor did he claim that it was. He was, however, the first to fuse the brass and steel so that the cross bar was an integral part of the balance. This method of manufacture enables the balance to be turned with an accuracy not obtainable, or only with much greater difficulty, when the rims were made as separate items and subsequently fixed to the cross bar. This of course was John Arnold's practice. Arnold made his rims flat and subsequently bent them to shape and screwed them to the cross bar. However, making an Earnshaw balance is not as simple as might be supposed since the brass is soft after fusing and has to be hammered to harden it. On slitting the rims the balance springs open and then has to be bent to correct it. Nevertheless despite these drawbacks the method developed by Earnshaw was soon to be universally adopted as far as this simple form of balance is concerned.

Earnshaw's weights were made from parts of a turned ring which explains their somewhat peculiar form. Later weights were cylindrical except for the streamlined weights as used by Brockbanks and Jürgensen (cat. no. 216). However there was little advantage in the slight degree of streamlining achieved by the use of these weights. A better approach to reducing the windage caused by the projecting weights was that employed by A. L. Breguet who sank the weights into the rim (cat. nos. 130, 153); this, however, was an expensive method.

Earnshaw's rims were short and relatively thin. He used the proportions of brass two or three times the thickness of the steel. Subsequently the rims became longer and thicker and the ideal proportions of approximately 3 of brass to 2 of steel became the norm.

In practice it was difficult to move the Earnshaw type of weights along the rims an equal distance while adjusting the degree of compensation. This was not so with Arnold weights which were mounted on screw extensions to the rims. Turning these weights through equal angles meant that they must move equal distances. However, various ways were developed of overcoming this difficulty with the Earnshaw weights as shown in some of the examples.

The Earnshaw balance in the pocket watch

Although the Earnshaw balance often appears in the marine form in pocket watches, it also often has the single weight at or near the end of the rim replaced by a number of screws. The rims are drilled and tapped in a number of positions sometimes regular and sometimes with a preponderance of holes near the end of the rim. Screws can then be moved nearer to or further from the end of the rim to adjust the temperature compensation. If necessary screws can be changed for similar screws of a different and denser metal. Thus brass screws can be changed for gold or gold for platinum. This, of course, will increase the degree of compensation.

Instead of the customary two timing screws normally found at each end of the bar in marine balances there are usually four quarter screws, as they are called, for the purpose of poising and bringing the balance and spring to time. In for example, cat. no. 111, these timing screws are reversed and project outwards from the rim. Nuts are then mounted friction-tight on these screws; such an arrangement is only found in the highest quality work.

Urban Jürgensen's 'Aerodynamic' (cat. no. 216)

Balance constructed in the fashion of John Arnold with separate rims screwed to the arm which has extended ribs for a secure fixing. The compensation and timing screws are shaped so as to minimise the air disturbance, hence the name aerodynamic. The rims are relatively short, leading to the conclusion that the balance was probably intended for use with a palladium spring.

Balances with more than two rims

The Earnshaw balance was also made with three or even four rims. Although these variants were used by the finest of makers, especially in France, there is in fact no advantage in using more than two rims. On the contrary it is more difficult to make and poise such a balance and it is more likely to go out of poise as it changes its shape with changes of temperature.

Berthoud three-arm balance (cat. no. 10)

At the end of each of the three rims is a complex weight with no less than four screws, these for adjusting poise, mean time and compensation. Not a sensible arrangement since adjustments of any one would upset the others. Adjustments to mean time and poise are best separated from compensation adjustments.

Berthoud-Motel (cat. no. 215)

A four-arm version similar to the Berthoud with its complex weights, this time four in number, but with, in addition, mean time screws at the ends of two opposed arms. Thus the adjustments for poise and mean time could be completely separated from the compensation adjustments.

II Balances with simple lamina as the rim

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
34			Arnold z		*c.* 1790	John Arnold & Son	CAI-1952
38			Arnold z		1787–99	John Arnold & Son	CAI-1579
40			Arnold z		*c.* 1800	J. R. Arnold	CAI-1581
41			Arnold z		*c.* 1802	J. R. Arnold	CAI-1580
42			Arnold z		1804	J. R. Arnold	CAI-1937
43			Arnold z		1804	J. R. Arnold	CAI-1944
44			Arnold z		*c.* 1805	J. R. Arnold	CAI-1582
46		34	Arnold z	gold spring	1806	J. R. Arnold	CAI-1842
47			Arnold z		*c.* 1808	J. R. Arnold	CAI-1583
49			Arnold z		1818	J. R. Arnold	CAI-1843
54		38	Arnold z		1812	Chas Haley	CAI-1736
71			Arnold z		*c.* 1790	Eardley Norton	CAI-1940
167			Arnold z		*c.* 1800	A. L. Breguet	CAI-2121
	195		Arnold z	diam. 25·5, h. 3·0			CAI-3011a
35			Arnold oz		1787–99	J. Arnold & Son	CAI-1576
36		29	Arnold oz		1787–99	J. Arnold & Son	CAI-1577
37		30	Arnold oz		1787–99	J. Arnold & Son	CAI-1578
53		37	Arnold oz		1802–3	Thos Percival	CAI-1744
33			Arnold yz		1790	J. Arnold & Son	CAI-2069
	196	158	Arnold z and o	diam. 38.0, h. 4·5	*c.* 1805		1976, 2–2, 2
	197	158	Arnold z and o type	diam. 22·0, h. 0·6 watch size	*c.* 1805		CAI-3020c
63			Earnshaw two-arm	Patented by Thos Wright 1973	*c.* 1800	Thos Earnshaw (Tomlin)	CAI-1592
	198	158	Earnshaw two-arm	diam. 32·5, h. 5·0			1976, 2–2, 17
58			Earnshaw two-arm		*c.* 1795	Thos Earnshaw	CAI-1960
60			Earnshaw two-arm		*c.* 1800	Thos Earnshaw	CAI-1957
70			Earnshaw two-arm		*c.* 1810	Thos Earnshaw	CAI-1298
15			Earnshaw type two-arm		1820	J. F. Cole	CAI-1726
17		15	Earnshaw type two-arm		1820–30	Amaury	CAI-1837
20					1849	H. Robert	CAI-1955
21					*c.* 1870	J. Forrest	CAI-1597
22		19			*c.* 1870	Jules Jürgensen	CAI-1728
23					second half 19th century	P. Norris	CAI-1739
24			Earnshaw type two-arm		*c.* 1870	Anon	CAI-1836
25			Earnshaw type two-arm		late 19th century	Anon	CAI-1826
26			Earnshaw type two-arm		late 19th century	Anon	CAI-2388
27			Earnshaw type two-arm		late 19th century	Anon	CAI-3053
28		23	Earnshaw type two-arm		late 19th century	C. Nephew	CAI-1610
29			Earnshaw type two-arm		late 19th century	Ami Sandoz and Son	CAI-1750
31			Earnshaw type two-arm		*c.* 1905?	Anon	1972, 4–5, 1
45			Earnshaw type two-arm		*c.* 1806	J. R. Arnold	CAI-1840
48			Earnshaw type two-arm		probably 1811	J. R. Arnold	CAI-1844

II Balances with simple lamina as the rim (*cont.*)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
50			Earnshaw type two-arm		*c.* 1820	J. R. Arnold	CAI-1584
51			Earnshaw type two-arm		*c.* 1820	J. R. Arnold	CAI-1845
52			Earnshaw type two-arm		*c.* 1800	John Grant	CAI-1602
55			Earnshaw type two-arm		1818	Perigal & Brown	CAI-1737
56		40	Earnshaw type two-arm		*c.* 1820	Urban Jürgensen	CAI-1605
75		50	Earnshaw type two-arm		1800–16	Reid	CAI-1747
76			Earnshaw type two-arm		*c.* 1810	C. Haley	CAI-1603
77			Earnshaw type two-arm		1810	R. Pennington	CAI-1738
79			Earnshaw type two-arm		1815	Ellicott	CAI-1735
82			Earnshaw type two-arm		*c.* 1820	Barraud	CAI-1939
83		55	Earnshaw type two-arm		*c.* 1820	Breguet et Fils	CAI-1721
85			Earnshaw type two-arm		*c.* 1820	Ellicott	CAI-1596
86			Earnshaw type two-arm		*c.* 1820	A. Mesure	CAI-1729
88			Earnshaw type two-arm		1822	Barwise & Sons	CAI-1847
89			Earnshaw type two-arm		*c.* 1825	Breguet et Fils	CAI-1849
90			Earnshaw type two-arm	cut midway	*c.* 1825	W. & J. Baird	CAI-1586
91			Earnshaw type two-arm		*c.* 1825	Barwise	CAI-1927
92			Earnshaw type two-arm		1829	Breguet et Fils	CAI-1935
93			Earnshaw type two-arm		*c.* 1830	Parkinson	CAI-1740
94			Earnshaw type two-arm		1837	W. & B. Clarke	CAI-1725
95			Earnshaw type two-arm		1837	Barwise & Sons	CAI-1846
96			Earnshaw type two-arm		1835/42	Rand H Molyneux	CAI-1608
97			Earnshaw type two-arm		*c.* 1840	E. J. Dent	CAI-1590
98			Earnshaw type two-arm		*c.* 1850	J. McCabe	CAI-1607
100			Earnshaw type two-arm		*c.* 1850	H. Golay	CAI-1601
101			Earnshaw type two-arm		1851	E. J. Dent	CAI-1591
102			Earnshaw type two-arm		1857	W. E. Cribb	CAI-1727

II Balances with simple lamina as the rim (*cont.*)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
103			Earnshaw type two-arm		*c.* 1860	G. E. Mylne	CAI-1609
104			Earnshaw type two-arm		*c.* 1867	Chas Frodsham	CAI-1599
105			Earnshaw type two-arm		1869	Chas Frodsham	1972, 9–3, 5
106			Earnshaw type two-arm		*c.* 1870	John Bennett	CAI-1588
107			Earnshaw type two-arm		*c.* 1875	Chas Frodsham	CAI-1598
108			Earnshaw type two-arm		*c.* 1875	Frodsham & Son	CAI-1600
109			Earnshaw type two-arm		*c.* 1875	Auguste Berthoud	CAI-1951
111		73	Earnshaw type two-arm	with timing nuts	*c.* 1880	Chas Frodsham	CAI-1833
112			Earnshaw type two-arm		late 19th century	Parkinson & Frodsham	CAI-1741
113			Earnshaw type two-arm		late 19th century	Alex Watkins	CAI-1753
114			Earnshaw type two-arm		late 19th century	Webster & Son	CAI-1754
115			Earnshaw type two-arm		*c.* 1900	Richard Attenborough	CAI-1585
116			Earnshaw type two-arm		*c.* 1900	M. B. Lee	CAI-1606
117			Earnshaw type two-arm		1903	G. Edwarts	CAI-1734
127		91	Earnshaw type two-arm		1798	John Grant	CAI-1962
128			Earnshaw type two-arm		*c.* 1800	John Grant	CAI-1347
131		96	Earnshaw type two-arm		*c.* 1820	J. F. Cole	CAI-947
133			Earnshaw type two-arm		1833	Arnold & Dent	CAI-1929
134			Earnshaw type two-arm		*c.* 1840	J. F. Cole	CAI-946
135			Earnshaw type two-arm		*c.* 1846	E. J. Dent	CAI-981
136			Earnshaw type two-arm		*c.* 1880	V. Kullberg	CAI-1031
137		100	Earnshaw type two-arm		*c.* 1880	V. Kullberg	CAI-1030
138			Earnshaw type two-arm		1860–1910?	Hunt & Roskell	CAI-1150
139			Earnshaw type two-arm		late 19th century	Nicole Nielsen	CAI-1122
140		102	Earnshaw type two-arm		1881/2	A. Lange & Sohne	CAI-1135
142			Earnshaw type two-arm		*c.* 1900	L. Lerry	CAI-1130
143		105	Earnshaw type two-arm		*c.* 1900	Army & Navy	CAI-908

II Balances with simple lamina as the rim (*cont.*)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
144			Earnshaw type two-arm		1909	Army & Navy	1972, 9–3, 8
148			Earnshaw type two-arm		*c.* 1800	Brockbanks	CAI-1950
154		113	Earnshaw type two-arm		*c.* 1855	Thos Pritchard	CAI-1746
155		114	Earnshaw type two-arm		*c.* 1860	R. Thompson	CAI-1832
156			Earnshaw type two-arm		*c.* 1860	Anon	CAI-1829
157		115	Earnshaw type two-arm		*c.* 1865	Arnold & Lewis	CAI-1830
158			Earnshaw type two-arm		*c.* 1865	Anon	CAI-1742
159			Earnshaw type two-arm		*c.* 1865	E. Drake	CAI-1828
161			Earnshaw type two-arm		1870	C. Fasoldt	CAI-1199
	199		Earnshaw type two-arm	diam. 16·6, h. 1·4			1976, 2–2, 58
	200		Earnshaw type two-arm	not cut diam. 17·2, h. 1·5			1976, 2–2, 59
	201		Earnshaw type two-arm	diam. 41·7, h. 6·3			1976, 2–2, 18
	202		Earnshaw type two-arm	diam. 40·5, h. 7·7			1976, 2–2, 30
	203	158	Earnshaw type two-arm	diam. 39·5, h. 6·9		Thos Mercer Ltd	1976, 2–2, 32
	204		Earnshaw type two-arm	diam. 38·0, h. 4·6 4 rims (centre cut)			1976, 2–2, 35
	205		Earnshaw type two-arm	diam. 39.0, h. 4·3 not cut no weights			1976, 2–2, 36
	206		three-arm	diam. 30·0, h. 2·8			CAI-3012b
	207		two-arm	two timing nuts diam. 22·5, h. 2·3			CAI-3011b
	208		two-arm	curious relieved weights diam. 30·0, h. 4·9			CAI-3012a
	209		two-arm	not cut diam. 30·0, h. 5·0			CAI-3012d
162			Earnshaw type two-arm		*c.* 1870	C. Fasoldt	CAI-1204
168			Earnshaw type two-arm		*c.* 1818	Gibbons	CAI-1932
171			Earnshaw type two-arm		*c.* 1855	Jos. Bannister	CAI-1949
172			Earnshaw type two-arm		*c.* 1870	E. Coulliant	CAI-1959
173			Earnshaw type two-arm		late 19th century	Anon	CAI-1926
175			Earnshaw type two-arm		*c.* 1900	Anon	CAI-1984

II Balances with simple lamina as the rim (*cont.*)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
178			Earnshaw type two-arm		*c.* 1875	Chas Suchy et Fils	CAI-1835
179			Earnshaw type two-arm		*c.* 1880	Jas. Calame Robert	CAI-1138
180			Earnshaw type two-arm		late 19th century	Anon	CAI-3135
181			Earnshaw type two-arm		*c.* 1900	Anon	CAI-882
183			Earnshaw type two-arm		1902	Yeomans	CAI-1004
184			Earnshaw type two-arm		1908	Louis Desoutter	CAI-952
185			Earnshaw type two-arm		1933		CAI-1175
	210		Earnshaw type two-arm	diam. 33·2, h. 5·0			CAI-3370
	211		Earnshaw type two-arm	diam. 18·6, h. 1·4			CAI-3014b
	212		Earnshaw type two-arm	diam 16·6, h. 1·5 not yet split			CAI-3023b
	213		Earnshaw type two-arm	diam. 24·4, h. 2·6			CAI-3387
10			Earnshaw type but three-arm	Berthoud design	*c.* 1797	Louis Berthoud	CAI-1928
84			Earnshaw type but three-arm		1820	Ellicott	CAI-2091
87		57	Earnshaw type but three-arm		*c.* 1820	Chas Young	CAI-1945
132			Earnshaw type but three-arm		1828–32	Ulrich and Co.	CAI-1167
152		111	Earnshaw type three-arm		*c.* 1813	A. L. Breguet	1961, 7–2, 1
174			Earnshaw type three-arm		*c.* 1790	Geo Margetts	CAI-1942
176		141	Earnshaw type three-arm	Breguet's balance	1808	Arnold/Breguet	CAI-1848
	214	159	Earnshaw type three-arm	Berthoud's design diam. 20·0, h. 1·4			CAI-3393
13			Earnshaw type four-arm		1811	Louis Berthoud	CAI-1941
14			Earnshaw type four-arm		1813	J. R. Arnold	CAI-1938
16			Earnshaw type four-arm		*c.* 1826	H. Motel	CAI-1953
169			Earnshaw type four-arm		*c.* 1818	Lego	CAI-1930
	215	159	Earnshaw type four-arm	Berthoud's design diam. 23·8, h. 1·8			CAI-3392
153		112	Aerodynamic		*c.* 1835	Breguet et Fils	CAI-1189
130			Aerodynamic		*c.* 1813	Breguet et Fils	CAI-2066
	216	159	Aerodynamic	diam. 29·2, h. 4·3		Jurgensen	CAI-3388

III (cat. nos 217–233)

BALANCES WITH DEVICES TO LIMIT RIM MOVEMENTS AND BALANCES WITH AUXILIARIES

Once the existence of middle temperature error (MTE) had been established, attention was turned towards modifying the balances already in existence so as to nullify or at least substantially reduce this error.

This section deals with those balances with simple lamina as the rims but with devices limiting rim movement, that is those that *could* give non-continuous middle temperature error correction. Not all of these balances were, however, intended for this purpose, for those prior to 1840 had the rim movement limited merely to protect the balances against rough handling, and the amount of movement is not adjustable in any meaningful way.

Also included in this section are balances with secondary pieces or lamina known as auxiliaries. All of these balances were made with the intention of reducing MTE.

Poole's auxiliary compensation

Although it is possible that Hardy's balance was the first deliberate attempt to overcome MTE (see Section IV) and it is true that his balance can, in theory, be adjusted so as to do just that there is no proof that this is so and in fact it is unlikely. The evidence is that it was John Poole who, prior to 1842, invented the first really successful auxiliary knowing that it was MTE that he was attempting to overcome.[1]

The essence of Poole's balance was the provision of stops to limit the movement of the rims or at least to modify the way in which they move by restriction. Two small screws are carried by rigid arms fixed to the end of the arm. These screws are adjusted so as to meet the rims near their roots as they move outwards in low temperature. The effective length of the rims is thus effectively reduced, reducing the amount of compensation. Thus the total effect of MTE is considerably, but not uniformly, reduced. A chronometer could be adjusted so as to have a slight gaining error between 33 °C and 15 °C and a slight but increasing losing error between 15 °C and the temperature at which the rims meet the check screws. After this as the temperature falls further the error will be much reduced, the exact nature of the reduction depending upon the stiffness of the various parts of the balance involved and the position along the rim at which the screws touch. Thus the MTE is roughly halved between the two standard temperatures and considerably reduced in lower temperatures. However, the MTE is not eliminated, the correction is discontinuous in action, the adjustments difficult to make and unlikely to be stable. The popularity of this type of balance is no doubt due to the relative simplicity of the modification required to include it.

In its simplest form it is as in cat. no. 219, and this version has been used in a large number of chronometers as evidenced by the published trial results. During the years 1850–73 (the type of balance was not detailed in the records of the trials until 1850 and after) no less than sixty were actually described as having Poole's auxiliary, and only those chronometers in the first fifty were normally recorded. In the year 1877 no less than twenty-six were recorded and even as late as 1913 one was recorded in the Greenwich Trials with a palladium spring, the auxiliary acting in cold.

For the centenary of Breguet's death in 1923 a chronometer trial was held in Neuchâtel. This was, unusually, an international trial and the firm of Thos. Mercer submitted four chronometers. They all had Poole balances fitted with palladium springs. Mercer's were awarded a Group prize since they gained second, third, fourth, fifth and eighth places. The prize took the form of the Abraham-Louis Breguet medal.[2]

Eiffe's auxiliary

John Sweetman Eiffe (1800–80), a London maker, devised several forms of auxiliary, some of which were additions to an ordinary balance and some as integral parts of specially designed balances.

Eiffe's auxiliary consisted of two steel arms carrying screws at their free ends thinned near the root like a chronometer detent and curved to suit. The adjusting screw at the end of each arm controls the position at which the main rim picks up the auxiliary as it moves inward in heat. The size of the larger screw determines the effect that auxiliary has. This arrangement is the opposite of Poole's which acts in cold. In 1842 Eiffe submitted a paper to the Royal Society in which he described his auxiliary and went on to describe others, mostly little different to that described here, although one was mentioned that was to have a laminated arm. Eiffe's auxiliary was fitted to a marine chronometer in the 1850 trial, to another in 1852. About three a year were fitted to marine chronometers from 1854 to 1862 but no more after that.

One chronometer a year from 1855 to 1857 inclusive was fitted with 'Eiffe's New Patent'. It is not clear what the term means; but Eiffe did produce special balances to which his auxiliary was fitted.

Robert Molyneux's auxiliary

This auxiliary was designed at roughly the same time as Eiffe's (two chronometers fitted with Molyneux's auxiliary were tested at Greenwich in 1840). In essence it was the same as Eiffe's although arranged somewhat differently as the positions of the auxiliary arms were reversed and bridged with splits in the rims. A chronometer with this auxiliary performed extremely well at Greenwich in 1840. Molyneux described two more variants the second of which, his third form, has auxiliary weights mounted upon small secondary rims of their own. These rims are mounted inside the main rims on the cross bar. There were check pieces to limit their outward motion. Molyneux's work was of the highest order and some of his balances (see cat. no. 222) are jewelled where the check screws touch. The fourth chronometer in the trials in 1884 had this particular refinement.

Victor Kullberg's split rim (early form)

This balance is based on Molyneux's third form of balance but instead of their being separate auxiliary pieces the secondary lamina are cut out of the tail ends of the main rims. The result is that the balance is easier to make and more rigid.

Victor Kullberg's split rim (later form)

This form is a detailed rearrangement of the early form, the auxiliaries being positioned at the free ends of the main rims in front of the weights. In the example shown (cat. no. 229) the free part of the rim which carries the check screw is stiffened by the inclusion of a rib.

Thomas Mercer's balance

Mercer's balance has an auxiliary that can be arranged to work in either extreme of temperature. The balance is basically of the Earnshaw type, the auxiliary being two further bimetal strips fixed to the ends of the arm and inside the rims. If intended to act in lower temperature the outer of the two metals in the strips would be steel and vice versa for high temperature. Each strip carried a screw at its free end; the weight and position of these screws can of course be varied. A banking screw passes through the main rims into the auxiliaries and limits their free movement inwards.

The type shown in cat. no. 232 is one of the variants.[3] The brass is on the inside, thus these auxiliaries act in cold. The other balance, cat. no. 233, has only one auxiliary with the steel on the inside, and so acts in high temperatures.[4] Tony Mercer discussed only one type of balance in his book,[5] this being of the cat. no. 232 type.

Records in this same book,[6] which relate to chronometers sent to the Greenwich Trials, fail to indicate which had Mercer's special balance. However, Glasgow[4] says that Mercer had been very successful with his balance in the Greenwich Trials (by 1885 eight of his chronometers had gained a place in the trials). Mercer also made for others; in 1874 three out of the first five chronometers were made by him for Joseph Sewill, McGregor and Reid & Son respectively. The chronometer bearing Mercer's name came third. What is not clear is how many of the chronometers he made for others actually contained his balance.

Notes

1. Vaudrey Mercer, 'The Penningtons and Their Balances', *A.H.*, Spring 1981, pp. 514–22, and September 1981, p. 44.
2. Tony Mercer, *Mercer Chronometers*, Ashford 1978, pp. 73, 74.
3. F. J. Britten, *Former Watch and Clockmakers and Their Work*, London 1894, fig. 139, p. 224.
4. David Glasgow, *Watch and Clock Making*, London 1885, p. 256.
5. Tony Mercer, *Mercer Chronometers*, Ashford 1978, p. 67.
6. Ibid., pp. 71 and 207.

III Balances with devices to limit rim movement and balances with auxiliaries

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
118			Balances with limiting straps	limited outwards experimental	*c.* 1785	John Leroux	CAI-1038
125			Balances with limiting straps	Z type limited both ways	*c.* 1794	James Bullock	CAI-1934
	217		Balances with limiting straps	limited both ways; one timing weight missing; similar to cat. no. 68 diam. 24·2, h. 2·6			CAI-3033f
65			Earnshaw balance with two arms and with limiting straps	limited both ways	1807	Thomas Earnshaw	CAI-1593
66					1807	Thomas Earnshaw	CAI-1732
68				limited both ways		Brockbanks	CAI-1751
74			Earnshaw type balance and limited by screws	limited both ways	*c.* 1806	Brockbanks	CAI-1954
81			Earnshaw type balance; two-arm limited by screws	limited both ways	*c.* 1815	Barraud	CAI-1956
147			Earnshaw type balance but with three arms and limited by screws	limited both ways	*c.* 1785	Brockbanks	CAI-1723
150			Earnshaw type with three arms and limited by screws	limited both ways	1801	Brockbanks	CAI-1589

III Balances with devices to limit rim movement and balances with auxiliaries (*cont.*)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
177			Earnshaw type with two arms	limited both ways	1836	Hunt & Roskell	CAI-299
	218	159	Earnshaw type three arms, limited by screws	limited both ways diam. 40·0, h. 4·0		Brockbanks	1976, 2–2, 24
	219	159	Poole	diam. 36·5, h. 5·0	1842 onwards		CAI-3389
	220	159	Poole variant	diam. 33·8, h. 6·0	1842 onward		1976, 2–2, 19
	221	160	Poole variant	diam 39·1, h. 6·2	1842 onward		CAI-3371
	222	160	Molyneux jewelled affixes	both on one illustration diam. 41·5, h. 6·6	1840		CAI-3028j CAI-3028k
	223	160	Molyneux balance		1840		CAI-3380
78			Pennington		*c.* 1810	R. Pennington	CAI-1743
32			Pennington		*c.* 1790	J. Arnold & Son	CAI-1841
80			Pennington		1811–24	William Pickman	CAI-1745
	224	160	Pennington	diam. 31·1, h. 3·3			CAI-3033g
	225	160	Pennington	diam. 17·5, h. 1·8			1976, 2–2, 25
	226	160	Pennington	screws missing diam. 17·4, 2·3			1976, 2–2, 26
	227	160	Fletcher's Duplex	diam. 38·3, h. 6·0	1863?		CAI-3379
	228	161	Kullberg split rim	early form diam. 36·3, h. 6·0			1976, 2–2, 48
141			Kullberg split rim	early form	*c.* 1888	W. & G. Schoof	CAI-2070
	229	161	Kullberg split rim reversed	later form: for an example of this in a chronometer see NMM cat. no. CH 109/6521(e) diam. 37·5, h. 7·3			1976, 2–2, 49
	230		Kullberg split rim reversed	main rims not yet split			CAI-3381
	231		Kullberg split rim reversed	main rims not yet split			1976, 2–2, 51
	232	161	Mercer		before 1894		1976, 2–2, 34
	233	161	Mercer		before 1885		CAI-3391

IV (cat. nos 234–259)

BALANCES GIVING CONTINUOUS MIDDLE TEMPERATURE ERROR CORRECTION

The first of the balances with the potential for continuous MTE correction was developed by William Hardy in 1804. This was of a completely different type from Earnshaw's for it is not the rims but the arm that is bimetallic. The two metals are not fused together in Hardy's version. At the end of each arm is a stalk which carries compensation weights and as the temperature changes the angles the stalk subtends to the arm vary, thus altering the moment of inertia.

The exact method of construction varies. In cat. nos 73 and 234 the steel arm is on top and beneath are two brass strips, each end riveted to the ends of the steel arm. The fixing is not at the centre of the arm as stated by Gould.[1] The stalks are fixed to the steel which is weakened by being thinned just by the stalk, between it and the centre. In later balances of the Hardy type the two metals tend to be soldered or fused together.

Although this type of balance could be arranged so as to correct for MTE it is almost certain that this was not the intention. Furthermore such an adjustment would be exceedingly difficult to effect and probably the balance would be unstable and not maintain its performance. For the balance to correct for MTE the stalks would not be upright at the mean of the temperatures the timepiece was subjected to, but would instead be upright at the upper temperature. An examination of the examples in the Collection show that this is not so although these balances may of course have been tampered with since they were made.

Massey's balance

In 1814 Edward Massey patented a balance (Patent No. 3854) resembling Hardy's in appearance. However, in this design the stalks, not the bar, are bimetallic. They were slotted to reduce their mass so that they would respond more rapidly to changes in temperature, this in an attempt to match the rate of response of the balance spring. The result of course was merely to make the balance even more flimsy than Hardy's.[2]

The U-type balances of John Roger Arnold

John Roger Arnold also contributed to the development of the balance by making further modifications of the Hardy type balance. He was responsible for three different versions:

(1) The U-type,
(2) The U and O,
(3) The U and I.

As with the Hardy balance the arm is the bimetal component but is a simple lamina of the two metal fused together. All four examples in the Collection have platinum and silver, as opposed to brass and steel, in the arm.

The approximate ratios of the coefficients of linear expansion are as follows:

brass to steel 19:11
silver to platinum 19:8½

so that it can be seen that the silver/platinum combination will in fact give a greater degree of compensation, everything else being equal. In addition the silver/platinum combination is free from effects due to magnetism, a problem that was to become of increasing importance as the use of iron ships increased.

In the examples in cat. nos 235 and 236 the stalks that carry the weights are riveted to the arm; in the examples in cat. nos 43A and 237 the stalks are fixed by screws.

The U-type has timing screws on each stalk; the U and O type is similar but in addition has a ring like an extra small balance which carries three small weights used for poising purposes. The U and I type has timing and poising weights at each end of the arm and additionally a brass arm at right angles to the main arm which carries at each end a timing nut which can be used for both poising and timing purposes.

The Frodsham/Hartnup balances

The first of this family of balances, cat. no. 245, is to some extent a variant of the staple balance with the same single bimetallic cross arm but with the staple flattened so as to become a straight lamina. In this case the cross arm is very broad. The balance also resembles the J. R. Arnold 'U and I' balance. It has the same cross arm for timing/poising purposes. The compensation weights are mounted on threaded stalks, but these stalks are on the end of the 'flattened staples' which multiplies the action as compared with the J. R. Arnold 'U and I' balances.

This balance is probably experimental in nature and is possibly a forerunner of the Frodsham/Hartnup type of balance. The Hartnup standard balance is characterised by two features: the S-shaped bar and the inclined rim. It is the S-shaped bar constituent that characterises the Frodsham/Hartnup balances which however do not have inclined rims. Cat. no. 246 has a conventional bimetal rim fixed about a third of the way along, to the end of the S-shaped rim. Thus there are two parts of each half of the rim acting.

Cat. no. 247 has the various sections of the arm screwed together, unlike cat. no. 246 where the changeover is accomplished by machining steps and fusing the metals together. In this example the rim is an extension of the arm and in the same plane, thus producing a curious combination of types which could justifiably be called the Frodsham/Hartnup/Kullberg balance. There is a separate 'I' piece mounted beneath the main balance which has a broad arm and carries a large timing/poising screw at each end (one screw missing). Cat. no. 248 has the same basic S construction with an extra pair of bimetal arms lapping back over the 'S', each of which carries a short stalk with weight. These weights are threaded and there is a recessed locking nut to prevent accidental movement of the compensation weight. Again there is an 'I' arm carrying timing/poising nuts and most ingeniously a further pair of timing screws mounted nearly vertically. This mounting, which is slightly off the vertical, gives an extremely fine adjustment to the rate. Cat. no. 249 is a plain S-type balance with very short stalks and compensation nuts with locking nuts above. The 'S' component is mounted on a two-arm steel balance with timing/poising screws and nuts mounted on the arm. There are fine adjustment screws mounted in one of a series of three holes near the end of the arms of the 'S' with another pair on the central arm.

The Arnold/Dent staple balances

These balances are yet another development of the Hardy type of balance with a further complication, namely that weights are mounted on stalks that are themselves lamina.

The first of the types, cat. no. 239, is similar to a U and I balance but with the weights mounted on flattened U-shaped lamina, the steel being on the outside of the U. The second, cat. no. 240, is like a U balance with the weights mounted on lyre-shaped lamina. The third, cat. no. 241, is again like a U and I balance but with each weight mounted on two straight lamina made into the form of a U by uniting them at the U 'bottom' with a brass bush.

In each of these three balances the bimetal arm is of brass and steel not platinum and silver. (All three types were the subject of a patent, No. 9302 of 1842.)

The Dent Double L and Double N balances

These balances are built up on basic balances of brass which have two lamina mounted upon them. The lamina work in a horizontal plane and are thus quite different to the staple balances. Cat. no. 243 has a single arm which must have complicated poising. The other two examples have their lamina mounted on flat four-arm brass balances. Cat. no. 244 has similar shaped lamina to cat. no. 243 but has a poising/timing screw near each end of the arms.

Cat. no. 242, the double L balance, has only two poising/timing screws. The lamina are noticeably longer than those in the two double N balances which may account for the fact that the compensation weights are much smaller, the double N weights being very large, as was probably necessary because of their relatively small movements, which are not even fully effective because of the path they follow when in action.

Kullberg's 'flat rim' balance

Victor Kullberg was the first to produce a Hardy type balance that was truly successful. In this version the rims are composed of bimetallic strips in the plane of the balance, a very rigid construction particularly free from centrifugal distortion. Once again the bar has to be a bimetallic strip but the balance is particularly easy to make and hardening the brass becomes a simple matter.

The Kullberg 'flat rim' was used in chronometers in the Greenwich Trials from 1862 to 1873 at an average rate of two a year. From 1895 to 1914 it was used with a palladium spring, being included in a much higher average of fourteen a year. In one year, 1897, no less than thirty-five chronometers had this balance and spring!

Glass balances and springs

Glass balance springs are discussed in section XIII. (Glass springs were not always associated with glass balances as is the case in cat. no. 276.) These glass balances as in cat. no. 238 have two or four upright lamina to effect residual compensation, residual because correction is required for small effects only. The lamina are composed of platinum and silver and are found to be sufficient in their action without the addition of any weights at their free end although two of those in cat. no. 238 have very small screws at their free end. The four lamina in cat. no. 238 are set into brass brackets; these brackets are riveted to the flat glass disc that comprises the balance. The brackets also carry poising and timing screws.

During experiments on a glass balance and spring, the balance being without affixes and with the chronometer brought to mean time at 32° F, it was found to be only 40 seconds a day slow at 100 °F. Compare this with almost 6 minutes a day for a brass balance and steel spring and the superiority of glass in this respect is self-evident. Glass is normally quoted as having a coefficient of linear expansion of about half that of brass, so that it must be the great difference in the temperature coefficient of Young's Modulus of the glass spring that is responsible for the greatly decreased temperature errors.

Frodsham compound triple equation balance

This complex balance lives up to its name. It has a normal steel cross arm which has at each end two bimetal rims. One is normal and carries a segment-shaped weight, the other is a reversed rim (with the steel on the outside). At the end of each of these rims is a steel bar running back across the balance and carrying a large weight. These weights are thus made to follow a complex path, the effect of which could doubtless only be determined empirically.

Dent balance

Cat. no. 252 is a Dent balance (or part of a balance, it is not entirely clear which) similar to a Massey balance. The bimetal stalks are very short and stiff and carry very large weights. It is possible, although unlikely, that it is merely a secondary bar intended to correct for the minor errors of MTE and is now separated from its original companion balance. The cross bar is of steel. The inclination of the stalks from the vertical at room temperature is very noticeable in this balance.

Notes

1. Gould 1923, p. 187.
2. *H.J.*, March 1878, p. 96.

IV Balances giving continuous middle temperature error correction

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
73			Hardy		c. 1805	William Hardy	CAI-1958
170			Hardy type	arm materials fused together	c. 1830	Ulrich	CAI-1943
	234		Hardy type	sliding weights diam. 40·7, h. 24·5	c. 1805		1976, 2–2, 27
	235		J. R. Arnold U (type 1)	platinum and silver arm; sliding weights diam. 33·8, h. 13·0	1821	J. R. Arnold	CAI-3374
43A			J. R. Arnold U+O (type 2)	platinum and silver arm; gold spring c. 1825		J. R. Arnold	1978, 12–3, 1
	236	161	J. R. Arnold U+O (type 2)	platinum and silver arm diam. 16·3, h. 13·0	c. 1825	J. R. Arnold	1976, 2–2, 3

IV Balances giving continuous middle temperature error correction (*cont.*)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
	237	161	J. R. Arnold U+I	platinum and silver arm diam. 36·0, h. 18·0	*c.* 1825	J. R. Arnold	1976, 2–2, 4
	238	162	Arnold/Dent glass balance and spring	diam. 35·0	1836		CAI-3394
	239	162	Arnold/Dent staple	with bimetallic arm diam. 41·5, h. 10·0	Patent 9302 of 1842	Dent	CAI-3383
	240	162	Arnold/Dent staple	with bimetallic arm diam 30·0, h. 16·0	Patent 9302 of 1842	Dent	1976, 2–2, 10
	241	162	Arnold/Dent modified staple	with bimetallic arm diam. 46·0, h. 12.0	Patent 9302 of 1842	Dent	1976, 2–2, 5
	242	162	Dent double L	diam. 33.0, h. 6·0 basic balance of brass with brass and steel lamina	Patent 9302 of 1842	Dent	1976, 2–2, 11
	243	162	Dent double N	diam. 12·0, h. 7·5	Patent 9302 of 1842	Dent	1976, 2–2, 6
	244	163	Dent double N	diam. 38·5, h. 7·5 basic balance of brass with brass and steel lamina	Patent 9302 of 1842	Dent	1976, 2–2, 7
	245	163	Frodsham	diam. 39·5, h. 16·5 see Technical Introduction	*c.* 1850	C. Frodsham	1976, 2–2, 8
	246	163	Frodsham/Hartnup	diam. 41·5, 6·0	*c.* 1850	C. Frodsham	1976, 2–2, 44
	247	163	Frodsham/Hartnup	diam. 38·5, h. 3·5	*c.* 1850	C. Frodsham	1976, 2–2, 43
	248		Frodsham/Hartnup	diam. 37·2, h. 13·0	*c.* 1850		CAI-3375
	249	163	Frodsham/Hartnup	diam. 26·2, h. 8·1		C. Frodsham	1976, 2–2, 13
110			Frodsham/Hartnup	balance fitted later weights missing	probably 1880	Callier	CAI-1931
	250	163	Frodsham	diam. 33·0, h. 8·2		C. Frodsham	1976, 2–2, 16
	251	164	Frodsham compound triple equation	exhibited in 1862 exhibition diam. 33·0, h. 9·0	1862	C. Frodsham	1976, 2–2, 14
	252	164	Dent	l. 44·4	*c.* 1870	Dent	CAI-3376
	253	164	Fritz	diam. 41·2, h. 8·8			1976, 2–2, 28
	254	164	Kullberg bar and two rims	diam. 36·4, h. 8·9		Kullberg	1976, 2–2, 46
	255	164	Kullberg flat rim	for an example in a marine chronometer see NMM cat. no. Ch 164 A 72–13 (11) L diam. 36·0, h. 10·8	*c.* 1860	Kullberg	1976, 2–2, 47
	256		Kullberg flat rim	not yet split diam. 41·8, h. 8·5	*c.* 1860	Kullberg	CAI-3377
	257		Kullberg flat rim	diam. 36·5, h. 10·5	*c.* 1860	Kullberg	CAI-3378
	258		Kullberg flat rim	diam. 36·5, h. 11·4	*c.* 1860	Kullberg	CAI-3001a
	259	165	combination of Hardy and Earnshaw type balance	screws and nuts missing from Earnshaw part of balance diam. 34·2, h. 6·5		Frodsham/Arnold	1976, 2–2, 15

V (cat. nos 260–273)

BALANCES WITH SPECIALLY SHAPED RIM LAMINA AND WITH INCLINED LAMINA, ALSO CONTINUOUSLY ACTING AS IN SECTION IV

Contains three sub-sections, namely balances whose rim lamina are inclined to the main plane of the balance, those with specially shaped rim lamina and two experimental pieces.

The Hartnup balance

The Hartnup balance was another design which achieved similar results to the Hardy type, that is the weights moved in a compound way and so could achieve the desired MTE correction. It was designed in 1849 by John Hartnup, Superintendent of the Liverpool Observatory.

Although Hartnup together with his chronometer maker William Shepherd achieved good results with the balance, it was difficult to make and other chronometer makers never achieved results as good. The early Hartnup balance had a plain arm, only the rims being bimetallic, but it was difficult to achieve sufficient compensation with this arrangement and the developed version had a triple arm with all three arms being bimetal. The central arm had the steel underneath but the two outer arms had the brass underneath. Thus there was a leverage effect with the inclined rims supplying additional and non-linear movement of the weights.

The Hartnup 'Grid Iron', as his balance was commonly called, was fitted to chronometers in the Greenwich Trials during the years 1857 to 1863. For two of these years no less than nine chronometers had Hartnup's balance. After a gap of four years it was used in both 1867 and 1868 after which it fell into disuse.

E. J. Dent's prismatic balance, invented 1851

This balance had rims whose section showed a triangular side to the steel part of the bimetallic rim, at the junction of the steel and brass. (Frederick Dent modified this in layout, although not in principle, by putting the triangular side on the brass.) The object was to effect the correction of MTE by virtue of the fact that the lamina would bend more easily inwards than out. This is essentially the same as Kullberg's hollow rim where again the rim becomes stiffer and less easily bent in cold than it is when the weights are moving outwards in heat.

Kullberg's hollow rim balance

In this balance the brass portion of the rims are turned hollow like a pulley, hence the alternative name for this balance: the Kullberg pulley.

V Balances with specially shaped rim lamina and with inclined lamina, also continuously acting as in section IV

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
	260	165	Early Hartnup	diam. 43·2, h. 6·3	1849		CAI-3382
	261	165	Hartnup developed form	for an example in a chronometer see cat. no. Ch 4659–1 (6) at NMM			1976, 2–2, 39
	262		Hartnup developed form	not yet split diam. 33·6, h. 5·6			CAI-3384
	263		Hartnup developed form	complete with blued steel helical spring diam. 35·0, h. 7·0			CAI-3003
	264		Hartnup developed form	no weights or screws diam. 29·5, h. 4·6			CAI-3032a
	265		Hartnup developed form	diam. 31·5, h. 7·0			CAI-3032b
	266	165	Hartnup variant	diam. 37·6, h. 7·0			1976, 2–2, 38
	267	165	Hartnup variant	diam. 41·7, h. 5·8			1976, 2–2, 41
	268	165	Hartnup variant	diam. 49·1, h. 6·2			1976, 2–2, 40
	269	166	Hartnup variant	diam. 44·2, h. 6·9			1976, 2–2, 45
	270	166	Dent prismatic	diam. 38·8, h. 6·2			1976, 2–2, 12
	271	166	Kullberg low rim	not yet split diam. 33·2, h. 4·3			1976, 2–2, 42
	272	166	Kullberg hollow rim	diam. 40·7, h. 8·3			1976, 2–2, 50
	273	166	Woerd	diam. 41·2, h. 6·8	1878		1976, 2–2, 22

The theory behind the design is that as the brass expands the groove tends to flatten and thus slightly lessens the resistance of the rim to bending. In cold the reverse should happen with the resistance to bending being increased. Hence the result should be similar to that intended with the prismatic balance.

The Woerd balance

This balance was patented in England in 1878 by Charles Vander Woerd, an American. It was a bimetallic balance, the brass being of an unusual composition, namely equal parts of copper and zinc. However the brass was fused into a series of triangular-shaped saw cuts extending for just over one-sixth the circumference of the balance. It was intended to introduce a non-linear movement of the rim and to overcome MTE.[1]

Woerd found that his balance was much criticised in England and defended it in *H.J.* He signed himself 'Mechanical Superintendent of the Factory of the American Watch Company, Waltham Mass'. It would appear, however, that the claims for this balance could not be supported for it was certainly never used to any extent whatsoever.[2] The example in the Collection is for a marine chronometer and is certainly a fine piece of work.

Notes

1. For details of Charles Vander Woerd's balance see *H.J.*, September 1878, p. 14; October 1878, p. 22; December 1878, p. 44; February 1879, pp. 81–3.
2. In the issue of *H.J.* for December 1878, (pp. 44 and 45) it was reported that a very similar balance was shown in the Paris Exhibition. This was designed by Patek Phillipe and Co. of Geneva. The main difference in the two designs lay in the fact that the Patek balance had a normal bimetallic construction (no saw cuts) extending over the same amount of the circumference as in the Woerd balance. Each claimed that the other had stolen the idea.

VI (cat. nos 274–281)

MERCURIAL BALANCES

Le Roy's use of mercury in a compensation balance has already been discussed in the Historical Introduction. Theoretically such a balance can be made to overcome MTE although in practice this is difficult to achieve. After Le Roy, J. G. Ulrich seems to have been the first to produce several forms of balance weight containing mercury, in 1827. Ulrich was not successful with his experiments and soon abandoned his attempts in this direction.

Balance by Scrymgeour

A number of experiments were then undertaken by James Scrymgeour, a Glasgow maker, during the period 1824 to 1830. An example of this type of balance is cat. no. 276. Scrymgeour found, however, that the continuity of the mercury in the tubes was easily broken by a knock on the box of the chronometer – an inherent danger with this type of device.

Loseby's mercurial balance

Loseby's balance consists of a normal bimetallic balance with a mercury tube at the end of each rim furthest from the arm. These mercury tubes are like miniature thermometers with the bulb secured to the rim and the tubes pointing inwards. Each tube has a little air in it to preserve the continuity of the mercury thread in the tube. For a rise in temperature a small quantity of mercury will be driven towards the balance centre and for a fall in temperature will recede from it. By varying the curvature and position of the tubes, the amount of change in the radius of gyration can be exactly adjusted to eliminate MTE. Loseby had success with his balance, gaining first place in the Greenwich Trials in 1845, 1846, 1850, 1851 and 1852.[1]

VI Mercurial balances

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
99			Loseby	invented *c.* 1843	*c.* 1850	Loseby	CAI-1933
	274	166	Loseby/Gardner	for an example in a chronometer see cat. no. CL169A72–13 (16) L in the NMM diam. 41·4, h. 9·4			CAI-3372
	275	167	Loseby/Webster	diam. 42·0, h. 10·1	*c.* 1850		CAI-3373
	276	167	Scrymgeour	has a glass spring with flexible stud diam. 37·0, h. 11·0	1828		CAI-3073
	277	175	Loseby/Webster	tube only l. 21·4			CAI-3029a
	278	175	Loseby/Webster	tube only l. 21·6			CAI-3029c
	279		Loseby	tube only; similar to cat. no. 274			CAI-3021a
	280		Loseby	tube only; similar to cat. no. 274			CAI-3021b
	281		Loseby	tube only; similar to cat. no. 274			CAI-3021c

There was then a gap of many years before the Loseby balance was used again although never with the same degree of success. In 1898, 1902 and 1909 Reid and Sons submitted chronometers with Loseby type balances. In 1893 Robert Gardner entered a chronometer with a Loseby type balance with improved mountings for the tubes. In 1899 he entered two chronometers with the same type of balance, but after this he used the Guillaume balance (see Section VIII).

Note

1. E. T. Loseby, 'Improvements in chronometers', *Nautical Magazine* 1845; *An Account of Improvements in chronometers, watches and clocks*, London, 1852.

VII (cat. nos 282–285)

LUND'S COMPENSATION WEIGHTS

This device is an ingenious attempt to overcome MTE by means of special weights which could be fitted to any standard balance instead of plain weights.

The Lund weight has a base plate which carries two pivoted levers. One of these levers carries a brass weight while the other is acted on by the free end of a bimetallic strip which encircles the whole device and whose other end is fixed rigidly to the base plate. The levers are interconnected through one or two screws which bear upon two jewelled nibs. These screws are carried by the lever which also has a jewelled nib which is acted upon by the bimetallic strip. Thus any movement of the strip will result in an inward movement of the brass weight. The whole is biased by a weak spring so as to keep the levers in permanent contact.

At middle temperature the system is adjusted so that the weight is at its furthest from the balance centre, with both screws bearing equally on the jewelled nibs. With a rise in temperature the ends of the bimetallic strip separate; the lever moves and through the action of the screws on the nibs causes the weight to move towards the balance centre. Unexpectedly the same thing occurs, that is the weight moves inwards, when the temperature falls, this being the result of the geometry of the jewelled nibs. However the weight forms part of the main balance rim which is moving inwards and outwards under the influence of changes of temperature. What the small weight does is to introduce the desired irregularity of motion.

As the rim moves in, the action of the weight causes it effectively to move slightly faster than if the weight was plain and the difference increases with an increase in temperature. Conversely, in cold the auxiliary weight recedes at a slightly lower rate than the rim proper and again this effect is proportional to the change in temperature.

Although perfect in theory, the very small size of these weights made their manufacture very difficult and their adjustment equally so. In addition it could hardly be expected that once these adjustments were completed they should remain permanently correct. The records of the Trials between the years 1850 and 1914 do not show a single balance fitted with these weights.

VIII (cat. nos 286–289)

THE GUILLAUME BALANCE (also called Invar, nickel steel and the Gardner)

In this balance the required movement of the compensation weights to achieve correct compensation is effected by substituting a special alloy for what would be the steel of the normal brass and steel balance. This alloy has the characteristic of expanding non-linearly over the range 0° to 40 °C. Coupling it with brass in a bimetallic rim will therefore produce a balance whose characteristics will also be non-linear. It has proved possible to achieve temperature errors as low as $\frac{1}{50}$ second per degree centigrade, thus the entire change over the range normally tested would be less than 1 second/day.

However such results can only be achieved with Guillaume balances by selection for once the balance has been made it cannot be further adjusted to achieve the desired non-linearity. The general magnitude of compensation can of course be adjusted in the normal way, by the distribution of masses along the rim. These balances have a second advantage inasmuch as they have a greater compensating effect, thus enabling the rims to be made thicker and, by cutting them nearer to or at the middle, shorter, so reducing centrifugal errors.

Despite the tremendous success of this type of balance as evidenced by the records of the Kew Observatory and subsequently those of the National Physical Laboratory it was not much used by the English. Only four examples were sent to the Admiralty trials.

Robert Gardner who settled in London in 1886 as a chronometer maker introduced the balance into England. He took first place in the Greenwich Trials in 1897–98 not with a Guillaume balance, but with a balance with an auxiliary and a palladium spring. In 1900 he entered two chronometers, one with what he called his Gardner No. 1 balance with a steel spring and the other with a Gardner No. 2 balance with a palladium

VII Compensation weights

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
	282	167, 168	Lund's weights	diam. 10.0, h. 7			1976, 2–2, 65
	283	168	Lund's weights	diam. 11·3, h. 9·0			1976, 2–2, 66
	284	168	Lund's weights	diam. 11·5, h. 6·5			CAI-3020a
	285	169	Variant on Lund weight	diam. 13·8, h. 8·0	Patent 3396, 1867	A. M. Clark	CAI-3020b

spring. Another was entered in 1901 which had a Gardner No. 1 balance and this did better than the first two, achieving sixth place. In August 1901 he went to see Dr Guillaume to obtain a contract for sole agency for the 'Invar' balance as it was then generally called. Soon after this, however, his health failed and the contract was cancelled by mutual consent.

Frodsham entered a chronometer in 1903 with a balance described as being 'nickel steel' which we must also assume was a Guillaume. This was not particularly outstanding in performance. These are all that are known before the cessation of the Greenwich Trials in 1915.

As far as watches were concerned, however, the Guillaume balance soon dominated the field after its first appearance in the Kew Trials in 1912, and by 1914 no successful watch contained any other type of balance. By 1916 a separate column was devoted to the balance used in each watch and one can pick out the English firms who competed simply by looking for ordinary brass and steel balances.

In 1929 the first twenty-two of the watches tested at the National Physical Laboratory at Teddington had Guillaume balances. Victor Kullberg who died in 1890 would have been sad to see a watch bearing his illustrious name taking twenty-eighth place with a brass and steel balance. In fairness, however, the point must be made that the top twenty-two watches were all deck watches and that the Kullberg was an ordinary pocket watch.

By 1934 all twenty-four watches reported had Guillaume balances. They were submitted by the following firms, all Swiss: Omega, Zenith, Patek Phillipe, Longines and Tavannes.

IX (cat. nos 290–292, 326)

MONOMETALLIC BALANCES WITH AFFIXES FOR USE WITH SPRINGS WITH LOW THERMO-ELASTIC COEFFICIENTS

In about 1919 monometallic balances were fitted with affixes to give a mean of correction for the small remaining errors of top grade 'self-compensating' springs.

Three such balances as designed by Paul Ditisheim are cat. nos 290, 291, 292 the first being complete with its spring.[1]

Ditisheim got superb results with his balances but others did not seem to be able to repeat his success and the Guillaume balance remained supreme.[2] These balances were referred to as 'integral', a term which also covered monometallic balances without affixes.[3] It is not correct to refer to all of this type of balance as uncut for Ditisheim patented a cut type with the affixes in guide slots.[4] The balance although cut is still, however, basically monometallic. This is no doubt the type of balance in the pocket watches that obtained places in the National Physical Laboratory trials in 1927 and after.

Notes

1. Paul Ditisheim was a superb adjuster of watches (see Chamberlain 1941, p. 65).
2. Only recently have springs of a self-compensating type been produced that can equal the steel spring/Guillaume

VIII The Guillaume balance (also called Invar, nickel steel and the Gardner)

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
145			Guillaume		c. 1915	Ditisheim	1972, 9–3, 11
	286	169	Guillaume	diam. 42·4, h. 6·5			1976, 2–2, 29
182			Guillaume		1903	Carley & Clemence	CAI-1724
30			Guillaume		c. 1900	A. H. Potter	CAI-1834
	287	169	Guillaume	diam. 25·0, h. 2·0			1976, 2–2, 53i
	288		Guillaume	not cut diam. 22·5, h. 1·8			1976, 2–2, 57
	289	169	Guillaume	not cut, with stiffening ribs diam. 15·5, h. 1.3			1976, 2–2, 56

IX Monometallic balances with affixes for use with springs with low thermo-elastic coefficients

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
146			Ditisheim		c. 1930	Solvil	CAI-1198
	290	169	Ditisheim	diam. 21·7, h. 1·4			1976, 2–2, 52
	291	169	Ditisheim	diam. 21·0, h. 1·5			1976, 2–2, 54
	292	170	Ditisheim type	gold balance diam. 24·7, h. 1·3			1976, 2–2, 53ii
	326	172	Ditisheim type	large demonstration piece with stops for the lamina diam. 100, h. 5·9			1976, 2–2, 68

balance combination. These are used with ovalising balances, see Section X.

3. Gould seems to have been confused on this matter for he refers to the Guillaume balance as the 'integral', Gould 1923, p. 201. However an article by the National Physical Laboratory in the *H.J.* of February 1927, p. 120, leaves no doubt on the matter.
4. Patent 256,953; for details and an illustration see *H.J.*, January 1927, p. 108.

X (cat. nos 293, 294)

UNCUT OVALISING BALANCES FOR USE WITH 'SELF COMPENSATING SPRINGS'

The Hamilton Watch Company is to be credited with being the first to produce such superlative Ni-Span C spring material that it fully justified the use of a balance that could be adjusted so as to get rid of the major part of the small remaining temperature error. Hamiltons chose to use an ovalising balance for this purpose.

The first such balance was invented about 1915 by Charles Volet who was a colleague of Charles Edouard Guillaume. Volet collaborated with Paul Ditisheim in this invention. Gould mentions that Ditisheim had discussed the balance with him (*The Marine Chronometer*, footnote, p. 202). The balance is bimetallic but not cut. Instead the bar or arm is made of brass and the rim of steel. When the temperature changes the balance is thus caused to become oval and by grouping the screws nearer to or further away from the arm, adjustment can be made to the degree of compensation.

Another type of ovalising balance was the Straumann. This is unique inasmuch as it is monometallic. It was developed by M. R. Straumann of Waldenburg, an engineer, technician and director of a large Swiss watch factory. The same alteration from circular to elliptical is produced, but by simpler means. Certain metal crystals have different coefficients of expansion in different directions, e.g. zinc. If the fracture of a cast sheet of zinc alloy containing a certain percentage of cadmium or copper is examined microscopically, it will show a crystalline structure, crystals jumbled up without an orderly arrangement, the expansion on heating being the same in all directions. If this sheet is rolled the crystals will rearrange more or less longitudinally in the direction of rolling, and the sheet will have a greater coefficient of expansion along the line of rolling. The difference will be greater if pure zinc is used, which for various reasons is impracticable. The coefficient of expansion of the main axis longitudinally is 0·000064, whereas along an axis at right angles, or diametrically, it is 0·000013. One of the special alloys of the Straumann balance has a coefficient of expansion in the direction of rolling of 0·00003, and at right angles, 0·000008. The balances are cut out of the sheet so that the cross bar lies in the direction of rolling, consequently it lengthens proportionately with the application of heat and so reduces the transverse diameter. The rim is drilled and tapped with twelve holes at equal distances for the reception of compensating screws. A change of position of a pair of screws from the end of the bar to the middle of the rim will counteract the effect of a change of rate of one second per degree C per 24 hours, which is a normal error of an Elinvar spring. Patented in 1919 by the Thommen Factories of Waldenburg, it was called the 'anisotrophic' balance.

The Hamilton balance, although the same in principle, is different in detail, the arm being of Invar and the rim of stainless steel; the two are joined together by hard soldering. The balance can compensate for a spring with a slightly negative or slightly positive temperature coefficient merely by the exact distribution of the screws around the rim. A balance of this type is cat. no. 293.

An experimental balance by Mercer is a further example, cat. no. 294. This has an aluminium bar with a steel rim and is reminiscent of early balances inasmuch as it is screwed together; the screwing however is reinforced by cement. Three screws are used at each end of the cross bar which is lapped over the rim top. This balance proved unreliable in action.

XI (cat. no. 295)

AIRY'S BAR

Airy's bar is not a compensation device but helps in the fine adjustment of the ordinary compensation balance should it be without screws. Airy[1] had noted the difficulty of moving the compensation weights the small amount necessary during

X Uncut ovalising balances for use with 'self-compensating springs'

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
	293	170	Hamilton	two pairs of timing nuts, one for coarse adjustment and a smaller pair for fine adjustment	1944	Hamilton Watch Co	1976, 2–2, 55
117A		79	Hamilton	two pairs of timing nuts as above		Hamilton Watch Co	1988, 4–10, 2
	294	170	Hamilton	experimental diam. 44·5, h. 4·2	1965	Thos Mercer and sons	1976, 2–2, 33

adjustments and developed a device which consists of a crossbar fitting friction tight on the balance staff and carrying at either end a slender steel spring. On the end of each spring is a small weight, about a tenth of the size of the main weights. The springs are just strong enough to keep these small weights pressed against the inside of the rim. Accordingly they move in and out with the rims and can be considered from this point of view merely as an increase in the mass of the main weights. However slight alterations can be made to their effect by twisting the arm one way or the other, thus altering the amount of their travel.

However ingenious the idea it is in fact unnecessarily complicated. Brockbank effected minor alterations by changing the positions of screws set tangentially through the balance weights. There are also practical objections to Airy's method in that the pressure of weights against the rims is bound to affect their action and the amount of this interference will vary with different positions of the bar.

If the trade had been left to decide whether or not to adopt the device few would have been made, but Airy used his great influence to obtain Admiralty approval for an order made in October 1876 directing that all chronometers competing in the 1877 Trial were to be fitted with the bar. Understandably this order was not well received. It was a new and unproved device and furthermore could not be fitted to balances such as Hartnup's or Kullberg's. Furthermore its action on other balances with MTE correction was problematical. Representations to this effect were made to Airy who admitted their force and rescinded the order temporarily, although in fact it was never to be made compulsory. Airy nevertheless intimated that purchases by the Admiralty would be restricted to chronometers possessing his bar, but this was never to be the case.

In 1877, 25 of the 34 chronometers accepted had what was described as Airy's compensation.[2] Figures for subsequent years were: 1878 25 out of 30; 1879 24 out of 30; 1880 19 out of 44; 1881 15 out of 43; 1882 15 out of 46; 1883 6 out of 40; 1884 3 out of 34, 1885 3 out of 34; 1886 4 out of 40 and in 1887, for the first time since 1877, there were none. It had taken ten years for the device to die.

Notes

1. Sir George Biddell Airy KCB was Astronomer Royal, 1831–81.
2. There was constant confusion about the true purpose of Airy's invention, and he grew tired of explaining it. Even in the reports of the Admiralty Trials it is referred to as 'Airy's compensation'.

XII (cat. nos 296–301)

THE BALANCE SPRING IN ITS DIFFERENT FORMS

In Arnold's earliest timekeepers a flat spiral spring was used, the only type available at the time.

When Arnold devised his first compensation balance in 1775 he developed at the same time a helical balance spring. He objected to the spiral spring because, as he said to a Select Committee of the House of Commons:[1] 'It is never a spiral but when it is at rest; for the instant it begins to move it assumes a figure that is not a perfect spiral, both when the spring opens and closes by contrary vibrations'. A patent, no. 1113, for the helical spring was taken out in 1775.

He must have been disappointed with his helical spring, however, for it will not dilate in a uniform manner. By a stroke of genius he discovered the need for terminal curves which he patented as 'incurves' in 1782 (Patent No. 1328). This was the spring configuration that was to be used in almost every marine chronometer and many pocket chronometers up to the present.

Two variations on this form of spring were the conical spring and the spherical spring. The conical spring was almost without exception a French variant used by Louis Berthoud and H. Motel. It has no advantage over the helical spring. An example is cat. no. 16.

The spherical spring was first developed in Switzerland. The maker to whom it is attributed is F. Houriet and an example is to be found in cat. no. 177. It again has no advantage over the helical spring and is very difficult to make and polish.

Breguet was the first to apply a terminal curve to a flat spiral spring, which he had done by 1800. Edouard Phillips calculated the mathematics of a series of terminal curves that would give true dilation of the spiral spring which he published in 1861 (see Bibliography and a report in *H.J.* October 1863, pp. 13 and 14). Although a good starting point these exact curves are in fact no use in practice since the behaviour of the balance and spring has to be non-isochronous to offset escapement error. The curves thus have to be slightly modified to correct for the various timekeeping errors that are found to exist.

The Duo-in-Uno spring is said to have been developed by Mr Mairet of Baker Street, London and some were shown by Charles and John McLennan in the 1862 Exhibition. They had been used by A. P. Walsh since about 1860.[2] The spring enables a saving in height to be obtained, for some of the length of the helical spring is taken and at its lower end (next to the balance) formed into a spiral portion.

XI Airy's bar

Main cat. no.	Appendix cat. no.	Plate no.	Type of balance	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
	295	170	balance with Airy's bar	in use between 1877–88 diam. 39·0, h. 24·0		CAI-3390	
133			balance with Airy's bar	fitted later		Arnold & Dent	CAI-1929

The Tria-in-Uno is similar to the Duo-in-Uno but has a second spiral portion at the top (the stud end). The difficulties of making such a spring must have been such as to discourage almost everyone and these springs are in fact rare. Attributed to John Hammersley this spring must have been in use before 1887 as it was referred to by Saunier.[3]

Notes

1. Mercer 1972, p. 65.
2. The design of this spring was claimed by A. P. Walsh, but this is refuted in a letter to the *H.J.*, April 1894, p. 129.
3. Claudius Saunier, *A Treatise on Modern Horology*, trans. by Julien Tripplin and Edward Rigg, 1887, pp. 748, 749 and Pl XIX, fig. 19.

XIII (cat. nos 302–306

THE USE OF MATERIALS OTHER THAN STEEL FOR BALANCE SPRINGS

John Arnold was the first to make use of a material other than steel for balance springs using an alloy of gold, possibly in 1779. He claimed two benefits from not using steel, one being the avoidance of damage from moisture in the air and the other from perspiration from the fingers.[1]

Arnold 14/104 (cat. no. 33) has a gold spring, as does Arnold 176 (now in the Vancouver Maritime Museum). These two timepieces travelled with Captain Vancouver on his famous voyage around the world in 1798.[2] These gold springs are mentioned in letters to the Board of Longitude written in April and November 1790.[3] There is little doubt that the chronometers referred to are 14/104 and 176.

Arnold charged an extra four guineas for fitting a gold spring, i.e. another 20% on the total cost of a chronometer!

Elinvar Springs

Guillaume developed the alloy called Elinvar about 1912 which has a low thermo-elastic coefficient. This coefficient can be either positive or negative as its value is controlled by varying the composition, mechanical treatment, and heat treatment. The composition of this alloy is in general 35% nickel, 10% chromium and the remainder iron. Small additions are made of tungsten, carbon, silicon and manganese. The elastic limit can be raised only by cold-working, i.e. drawing and rolling, and to set the spring it must be heated in its spiral form. However, only low elastic limits are achieved with this particular alloy; they are of the order of 22 kg per sq. mm (15 tons per sq in). A steel spring will have an elastic limit four or five times as great as this and as a result Elinvar springs are very soft, easy to damage and elastically not very stable. This means they are not very suitable for high-quality timekeepers.

Since 1930 a number of superior alloys have been developed, and are well known by their trade names, Nivarox, Isoval and Ni-Span C. These are mostly of the precipitation hardening type which acquire their mechanical properties both from cold working and heat treatment; hence their elastic limit is not impaired during heat treatment, as with Elinvar and elastic limits up to 65 kg per sq mm, or 40 tons per sq in are obtained. Because their elastic limit is higher their stability is better than that of Elinvar. This is not an unexpected result since if working stresses are low in relation to the elastic limit changes in the nature of the material will be less likely to occur. Alloys of this kind with the

XII The balance spring in its different forms

Main cat. no.	Appendix cat. no.	Plate no.	Form of spring – some examples	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
87		57	flat spiral	no terminal curve but has resilient stud	c.. 1820	Charles Young	CAI-1945
22		19	flat spiral with terminal curve	100% curve	c. 1870	Jules Jurgensen	CAI-1728
13		12	helical	no terminal curves	1811	Louis Berthoud	CAI-1941
6		6	helical with terminal curves		1778	John Arnold	CAI-1839
	296	170	helical with terminal curve	diam 10·1, h. 9·3 with clamped stud			CAI-30129
	297	170	helical with terminal curve	diam 10·0, h. 8·8 with stud and collet			CAI-3012h
	298		helical with terminal curve				CAI-3025d
111		74	Duo in Uno	invented before 1862	c. 1880	Charles Frodsham	CAI-1833
	299		Duo in Uno				CAI-3025b
	300		Duo in Uno	diam. 9.0, h. 2·6			CAI-3025c
16		14	conical		1826	H. Motel	CAI-1953
177		143	spherical		1836	Hunt & Roskell	CAI-299
	301	171	Tria-in-Uno	diam. 9·0, h. 3·0			CAI-3025

exception of Nivarox (see below) will contain roughly 40% nickel, 5½% chromium, with the addition of small percentages of titanium and aluminium, as precipitation hardening elements. The remainder of the alloy will be iron, with small additions of silicon and manganese. In practice, the temperature errors obtained with springs of this type vary with the quality of the spring. First quality springs have a tolerance of approximately ±0·3 seconds per day per degree C; and second quality of ±2 seconds per day per degree C. The best quality is adequate for nearly all commercial work, even the highest grade. For observatory and competition work, however, these springs are in general not good enough; this is clearly shown by the fact that almost all watches awarded a high place in the observatory competitions were sprung with steel springs and a Guillaume balance. However, one spring made by the Hamilton Watch Co. of America is undoubtedly the best of its kind in the world and good enough to warrant the use of a residual compensation balance. It is exceedingly difficult to control the exact thermoelastic coefficient, but providing the spring is sufficiently stable to warrant residual compensation this will readily eradicate the very small temperature errors remaining.

Nivarox springs

Although there is as yet no example of a Nivarox balance spring in the Collection, it is impossible to discuss the different materials of which balance springs are made without mentioning these particular springs. Nivarox was developed at some time before 1926 by Carl Haas of Schramberg Germany. It is a nickel iron alloy with the addition of a small percentage of beryllium. By appropriate heat treatment it can be given a coefficient similar to steel or right down to a slightly negative coefficient. The material is rustless and non-magnetic. Unlike Elinvar springs they are highly resistant to accidental damage being, if anything, slightly tougher than steel. In Switzerland, M. R. Straumann produced a spring material with similar properties made from nickel, iron, chromium, molybdenum and beryllium. This was mentioned by A. L. Rawlings in the *Science of Clocks and Watches* (1948) p. 151, although he would seem to be mistaken about the constituents of the alloy.[4]

Tony Mercer in *Mercer Chronometers*, London 1978, relates the story of a chronometer tested under extreme temperature conditions in 1926. This chronometer he describes as having a monometallic Invar balance and a Nivarox balance spring (p. 76). In fact the balance has affixes. This chronometer No. 12827, is now in the Science Museum. It was given first prize in the test which was carried out for the British Engineers Standards Association.[5]

Glass balance springs

On 19 May, 1836, a paper was read to the Royal Society entitled 'On the application of glass as a substitute for metal balance springs'. This paper was published in the *Nautical Magazine* for December 1836 and reprinted in the *American Journal of Science* in 1837.

Frederick Rippon had been experimenting with balance springs of glass as early as 1833 but he was not the first, for Breguet made a chronometer which is reported by Gould as being in the Conservatoire National des Arts et Métiers that contained a glass balance (which he reports as broken) and a glass spring.[6]

Scrymgeour also experimented with glass balance springs (cat. no. 276) in about 1828. Although these glass balance springs were found to be anything but fragile and to require hardly any temperature correction, they were not found to be stable.

At least three marine chronometers were made by Dent with glass balance springs and glass balances. Two of these, nos. 616 and 790, were tested at the Royal Observatory and found to accelerate and to go on accelerating long after a chronometer with a steel spring would have done. Another Dent, No. 1771, was sold at auction in 1972.

XIII The use of materials other than steel for balance springs

Main cat. no.	Appendix cat. no.	Plate no.	Examples of materials other than steel	Notes (dimensions in mm)	Date	Maker	Registration no. MLA/
46			gold		1806	J. R. Arnold	CAI-1842
	302	171	glass (helical)	see cat. no. 276 and 238 for other examples		Dent	CAI-3009
145			Elinvar		*c.* 1930	Solvil Ditisheim	1972, 9–3, 11
142			palladium		*c.* 1900	K. Leroy	CAI-1130
	303		gold	helical diam. 11·7, h. 15·0			CAI-3025e
	304		gold	helical diam. 8·2, h. 7·0			CAI-3025f
	305		gold	helical diam. 11·9, h. 9·0			CAI-3025g
	306		gold	helical diam. 8·3, h. 3·0 with collet and stud			CAI-3025h

In view of the nature of glass, a super-cooled liquid which is in an unstable state, it is not surprising that it was found to be unsatisfactory for balance springs.

Notes

1. Letter to Lord Howe, 6 March 1784. Reproduced in Mercer 1972, p. 200.
2. Captain George Vancouver, *Voyage of Discovery*, 1798.
3. Mercer 1972, p. 201.
4. See also E. Jacquet and A. Chapvis, *Techniques and History of the Swiss Watch*, p. 208.
5. See also *H.J.*, August 1926, pp. 249, 250.
6. Gould 1923, p. 162.

XIV Further dissociated parts

Cat. no.	Plate no.	Description of part	Size and notes (dimensions in mm)	Registration no. MLA/
307		Part of a Kullberg flat rim balance	from a balance about diam. 34·0	CAI-3001b
308		Part of a Kullberg flat rim balance	from a balance about diam. 34·0	CAI-3001c
309	171	Experimental Earnshaw type balance with four weights secured by screws from within the rim and located in a groove on the outside of the rim. The weights each carry an arm which can take up to three screws for timing and fine adjustment of compensation. One weight missing	diam. 36·5, h. 3·4	1976, 2–2, 20
310		Balance weight	diam. 6·3, h. 5·6	CAI-3033d
311		Balance weight	diam. 6·2, h. 5·6	CAI-3033e
312	171	Balance blank, brass ring	diam. 34·0, h. 5·5	CAI-3031a
313	171	Balance blank, Mercer type, crossed out	diam. 32·2, h. 4·5	CAI-3031b
314	171	Balance blank, turned, crossed out, in the rough	diam. 31·2, h. 4·3	CAI-3031d
315	171	Balance not yet crossed out, with staff	diam. 27·5, h. 3·6	CAI-3031e
315A	171	Balance not yet crossed out	diam. 27·5, h. 3·6	CAI-3031c
316		Balance blank	diam. 27·5, h. 3·4	CAI-3369a
317		Balance blank, recessed	diam. 28·0, h. 2·6	CAI-3369b
318		Balance blank, recessed and crossed out	diam. 27·7, h. 3·6	CAI-3369c
319		Balance blank recessed, crossed out and split	diam. 28.0, h. 3·2	CAI-3369d
320	171	Balance, steel outside, brass inside. Steel centre fused into the brass arm. This is a 'thermometer' balance. No 'compensation' weights	diam. 21·2, h.. 2·6	CAI-3012c
321	172	Balance, brass and steel, cut with two weights only. Staff collet integral with arm, obviously not intended to be screwed to staff but to be a close fit	diam. 34·2, h. 7·8	CAI-3012e
322	172	Balance, brass and steel, two timing screws and two compensation weights complete with staff and rollers	diam. 23·7, h. 1·8	CAI-3012f
323	172	Balance, part finished, Earnshaw type, three-arm	diam. 21·0, h. 1·8	CAI-3019b
324		Balance blank turned, partly crossed out	diam. 12·8, h. 1·2	1976, 2–2, 63
325	172	Blank for balance of an experimental nature, cut and crossed out, steel part only	diam. 40·6, h. 2·2	1976, 2–2, 64
327	172	Experimental balance	diam. 43·2, h. 3·0	1976, 2–2, 60
328	173	Balance used as a thermometer with brass inside and steel outside	diam. 41·0, h. 5·0	1976, 2–2, 61
329	173	Uncut Earnshaw type experimental balance, unfinished	diam. 38·3, h. 6·5	1976, 2–2, 31
330		Blank for Hartnup balance, part turned	diam. 30·0, h. 3·2	1976, 2–2, 37
331		Blank for balance at stage where the brass fused onto steel	diam. 44·0, h. 6·0	1976, 2–2, 62
332	173	Experimental balance, broken. Basically Earnshaw type with two vanes on the very narrow arm	diam. 35·0, h. 8·2	1976, 2–2, 21
333	173	Experimental balance with two straight rims coming from the sides of the rhomboidal boss	l. 42·6	1976, 2–2, 9
334	173	Experimental balance with exceptionally thick bimetal rims, probably made with the intention of reducing centrifugal error	diam. 40·5, h. 4·7	1976, 2–2, 23
335	173	Experimental zinc and steel balance	diam. 36·4, h. 5·2 incomplete	CAI-3386
336	174	Experimental zinc and steel balance	diam. 35·0, h. 8·0	CAI-3385
337	174	Part of constant force escapement	about diam. 6·0, h. 13·0	CAI-3004b
338	174	Part of constant force escapement	l. 14·5	CAI-3004c
339	174	Part of constant force experiment	l. 12·0, h. 6·0	CAI-3028g
339A		Part of constant force escapement	l. 12·0, h. 5·5	CAI-3028i

XIV Further dissociated parts (*cont.*)

Cat. no.	Plate no.	Description of part	Size and notes (dimensions in mm)	Registration no. MLA/
340	174	Lever escape wheel of Robin type	diam. 8·5, h. 1·1	CAI-3034b
341	175	Chronometer escape wheel cut but not crossed out, brass	diam. 13·6	CAI-3005a
342	175	Chronometer escape wheel cut but not crossed out, brass	diam. 13·6	CAI-3005b
343	175	Chronometer escape wheel cut but not crossed out, brass	diam. 16·8	CAI-3005c
344	175	Chronometer escape wheel cut but not crossed out, brass	diam. 15·6	CAI-3005d
345		Chronometer escape wheel brass, twelve teeth	diam. 14·3	CAI-3002d
346		Chronometer escape wheel blank	diam. 17·0	CAI-3033a
347		Chronometer escape wheel blank	diam. 17·0	CAI-3033b
348		Chronometer escape wheel blank	diam. 17·0	CAI-3033c
349	175	Arnold type escape wheel	diam. 11·9	CAI-3030a
350	175	Compensation curb on a steel index	diam. 17·2	CAI-3006a
351	175	Spiral compensation strip on brass plate with steel index	brass plate diam. 27·0, l. of index 27·5	CAI-3006b
352	175	Compensation curb	l. 10·0	CAI-3008a
353	175	Compensation curb	l. 10·0	CAI-3008b
354	175	Compensation curb	l. 10·0	CAI-3008c
355	175	Bimetal strip with foot	l. 30·0	CAI-3029b
356		Steel collet for balance spring	part finished diam. 2·6	CAI-3018g
357		Steel collet for balance spring	part finished diam. 2·6	CAI-3018h
358		Steel collet for balance spring	part finished diam. 2·6	CAI-3018i
359		Steel collet for balance spring	part finished diam. 2·6	CAI-3018j
360	176	Detent blank	l. 24·0	CAI-3028a
361	176	Detent blank	l. 22·0	CAI-3028b
362	176	Detent blank	l. 23·0	CAI-3028c
363	176	Detent blank	l. 22·5	CAI-3028e
364	176	Detent blank still part of steel bar	length not relevant	CAI-3013a
365	176	Detent blank	l. 28·17	CAI-3013b
366	176	Peto discharge detent	l. 25·5	CAI-3028d
367		Impulse roller, sapphire	diam. 3·6	CAI-3016
368		Impulse roller, sapphire	diam. 3·7	CAI-3035
369		Impulse roller, steel	diam. 7·0	CAI-3018a
370		Impulse roller, steel	diam. 7·0	CAI-3018b
371		Impulse roller, steel	diam. 7·0	CAI-3018c
372		Impulse roller, steel	diam. 7·0	CAI-3018d
373		Impulse roller, steel	diam. 7·0	CAI-3018e
374		Impulse roller, steel	diam. 7·0	CAI-3018f
375		Impulse roller, steel with jewel	diam. 4·3	CAI-3028f
376		Impulse roller, steel with jewel	diam. 5·3	CAI-3028h
377		Impulse roller blank	diam. 7·0	CAI-3026a
378		Impulse roller blank	diam. 4·4	CAI-3026d
379		Discharge roller blank	diam. 1·5	CAI-3026b
380		Discharge roller blank	diam. 2·7	CAI-3026c
381		Motel-type pillar of steel but see cat. no. 16	h. over shoulders 14·8	CAI-3024m
382		Motel-type pillar of steel	h. over shoulders 14·8	CAI-3024n
383		Motel-type pillar of steel	h. over shoulders 14·8	CAI-3024o
384		Chronometer barrel arbor blank, half polished, with centres not yet removed	boss diam. 17·5	CAI-3312
385		Chronometer barrel arbor blank, half polished with centres not yet removed	boss diam. 17·5	CAI-3313

TECHNICAL DATA

I Marine Chronometers with Detent Escapements (dimensions in mm)

	Catalogue number	Centre distance: Balance/Escape wheel	Escape wheel diam. E (No. of teeth if not 15)	Impulse roller diam. I	Ratio E:I	Radius to tip of discharge jewel (approx.)	Length of detent to point of flexure (approx.)	Mainspring: height, thickness	Barrel: internal diam., height	Barrel: external diam., height	Balance (approx. dimensions): rim diam., height unless otherwise stated	Train: beats/hour	Duration (H hours, D days)
Anonymous	164	9·8	14·0	6·2	2·26:1	2·2	9·0	12·7, 0·28	29·8, 13·1	32·7, 15·4	28·1, 2·1	14,400	2 D
Anonymous	175	9·3	12·8	6·39	2·0:1	1·14	15·0	25·0, 0·39	46·4, 25·5	50·5, 30·0	22·4, 1·9	14,400	8 D
John Arnold No. 12	7	15·8	24·9	9·49	2·63:1	—	23·0	16·1, 0·56	43·5, 17·4	47·5, 19·9	46·0, 1·2	14,400	30 H
John Arnold and Son No. 14/104	33	11·25	19·6	4·87	4·0:1	1·6	23·0	19·1, 0·44–0·55	43·5, 20·0	49·0, 23·7	55·0, 5·5	14,400	30 H
John Arnold and Son No. 26	34	12·40	19·5	6·98	2·8:1	1·8	18·5	17·5, 0·45–0·58	43·5, 19·1	49·7, 22·0	47·4, 3·0	14,400	30 H
John Arnold and Son No. 106/196	39	11·50	17·0	7·13	2·39:1	1·8	21·0	33·0, 0·50	51·2, 34·7	56·3, 36·9	43·2, 5·8	14,400	2 D
John R. Arnold No. 217	42	9·9	13·2	7·46	1·77:1	1·6	18·0	13·6, 0·38	33·5, 13·9	37·1, 16·0	33·75, 3·6	14,400	30 H
John R. Arnold No. 223	43	9·60	14·5	5·45	2·66:1	2·0	17·0	31·7, 0·50	51·2, 33·9	54·3, 35·9	31·8, 3·9	14,400	8 D
John R. Arnold No. 413	14	9·10	missing	6·64	—	1·5	12·0	10·0, 0·28	27·6, 10·2	30·3, 12·0	22·7, 3·0	14,400	30 H
John R. Arnold No. 595	43A	9·0	12·4	5·80	2·14:1	1·6	13·0	12·6, 0·32	29·0, 12·8	30·7, 14·0	35·0, 16·0	14,400	30 H
Barraud No. 2/570 and 2/670	81	8·20	12·2	4·86	2·5:1	1·2	13·0	18·7, 0·35	32·1, 18·9	34·9, 21·0	22·0, 2·4	14,400	8 D
Barraud No. 982	82	9·70	14·4	5·97	2·41:1	1·3	17·0	29·0, 0·45	43·4, 29·6	46·5, 31·8	27·6, 3·4	14,400	8 D
Barwise No. 4307	91	14·40	21·4	8·8	2·43:1	2·0	25·0	17·9, 0·49	45·1, 18·7	47·8, 21·7	38·4, 4·7	14,400	30 H
Auguste Berthoud No. 293	109	7·9	11·6	4·82	2·4:1	1·18	12·0	10·8, 0·25	26·5, 11·1	28·4, 12·5	26·4, 2·1	14,400	2 D
Louis Berthoud No. 49	10	9·1	13·3(12)	6·43	2·07:1	1·8	8·5	6·3, 0·22	24·5, 6·5	26·4, 7·7	23·3, 1·3	18,000	30 H
Louis Berthoud No. 127	13	9·7	15·5	5·32	2·91:1	1·3	8·0	9·8, 0·26	29·9, 9·9	31·7, 11·7	27·0, 2·1	21,600	30 H
Breguet No. 4324	92	12·3	19·1(18)	6·6	2·9:1	1·57	15·0	32·2, 0·28–0·40	54·5, 33·2	57·3, 35·9	34·8, 3·30	14,400	8 D
Brockbank No. 436	148	11·40	15·4	7·84	1·97:1	1·68	20·0	17·0, 0·44	44·3, 17·5	47·9, 20·3	29·8, 4·7	14,400	30 H
Brockbank No. 632	74	9·8	13·4(12)	7·25	1·85:1	1·76	19·0	13·8, 0·34	33·8, 14·3	36·6, 15·9	29·7, 2·17	14,400	2 D
Callier No. 763	110	8·1	11·8	5·13	2·3:1	1·0	missing	missing	26·6, 10·7	28·4, 12·4	34·5, 2·1	14,400	2 D
Thomas Earnshaw No. 245/2264	58	8·0	12·1(12)	4·95	2·44:1	2·27	12·0	10·0, 0·35	28·3, 10·2	30·1, 12·0	28·4, 3·22	14,400	30 H
Thomas Earnshaw No. 509/2853	60	8·1	12·0(13)	5·41	2·22:1	1·44	14·0	11·4, 0·32	27·2, 11·7	29·9, 13·3	28·0, 2·80	15,600	30 H
Gibbons Patent Remontoire	168	11·4	15·0(12)	8·88	1·69:1	1·94	14·0	16·5, 0·30	26·8, 16·9	29·7, 18·9	27·1, 2·90	14,760	30 H
Hamilton Watch Co.	117A	10·0	13·15(16)	6·25	2·10:1	2·00	13·4	15·3, 0·42	38·0, 15·7	42·0, 18·5	40·5, 4·1	14,400	2 D
William Hardy No. 53	73	7·6	11·2	4·67	2·4:1	1·38	12·5	10·3, 0·32	27·5, 10·4	29·7, 12·4	bar 33·3 × 3·8 thickness 1·3	15,750	30 H
Edward T. Loseby No. 126	99	10·0	14·0	6·86	2·04:1	1·55	17·0	14·7, 0·36	32·7, 15·0	35·5, 17·2	29·4, 3·60	14,400	2 D
George Margetts No. 80	174	12·7	21·2(20)	4·88	4·34:1	1·91	19·5	29·0, 0·44	51·6, 32·0	55·1, 35·4	28·0, 1·72	14,400	8 D
Motel No. 44	16	10·0	15·6	5·4	2·89:1	1·5	8·5	10·3, 0·27	31·0, 10·4	32·0, 11·9	27·3, 2·1	18,000	30 H
Eardley Norton No. 2322	71	15·0	23·2	8·37	2·77:1	2·0	22·0	16·4, 0·65	58·3, 17·8	60·1, 20·4	39·9, 4·3	14,400	30 H
Henri Robert No. 58	20	10·0	15·0	5·97	2·51:1	1·8	10·0	20·0, 0·20–0·23	35·4, 20·7	33·0, 23·0	27·2, 2·6	13,500	2 D
Ulrich and Co. No. 2	170	10·9	14·6	7·72	1·89:1	2·0	18·0	41·0, 0·60	66·0, 45·4	71·4, 95·0	h = 45·4, l = 67·1 width 7·6	14,400	30 H
Charles Young No. 503	87	6·4	8·5	4·38	1·94:1	1·00	14·0	5·04, 0·24	19·4, 5·2	20·7, 6·3	23·0, 2·56	18,000	30 H

II Pocket Chronometers with Detent Escapements (dimensions in mm)

	Catalogue number	Centre distance: Balance/Escape wheel	Escape wheel diam. E (No. of teeth if not 15)	Impulse roller diam. I	Ratio E:I	Ratios to tip of discharge roller (approx.)	Length of detent to point of flexure (approx.)	Mainspring: height, thickness	Barrel: internal diam.	Balance: diam., height	Train: beats/hour	Notes
Anonymous 2144	25	6·32	7·7	4·52	1·70:1	0·9	8·5	2·75, 0·22	15·25	14·7, 1·78	18,000	
Anonymous 169	26	5·90	8·4	3·80	2·21:1	0·9	9·0	2·64, 0·19	16·50	17·2, 1·39	18,000	
Anonymous 26096	27	5·5	7·6	3·59	2·12:1	1·0	9·0	4·08, 0·21	15·0	15·0, 1·55	18,000	
Anonymous 5224/18	31	6·5	9·0	4·48	2·0:1	0·86	8·5	2·77, 0·22	17·7	15·5, 1·38	18,000	
Anonymous 20419	180	4·9	7·0	3·15	2·23:1	0·64	7·5	3·60, 2·22	17·0	14·2, 1·40	18,000	
Anonymous	12	6·08	10·70	3·68	3·0:1	0·94	14·0	3·30, 0·30	28·0	23·0, 0·75		
Anonymous	19	5·60	7·8	3·7	2·1:1	0·93	8·06	2·26, 0·22	18·2	18·1, 0·48	19,200	
Anonymous	24	5·20	7·26	3·24	2·24:1	0·89	9·10	3·18, 0·20	17·4	17·5, 1·20	18,000	
Amaury No. 11995	17	6·0	8·8	3·60	2·45:1	0·8	—	3·10, 0·23	19·6	17·5, 1·29	21,600	
John Arnold No. 3	4	7·8	10·50	5·40	1·94:1	1·25	6·70	5·50, 0·22	19·8	25·5, 0·72	18,000	
John Arnold No. 29	5	7·8	10·80	5·33	2·02:1	1·34	6·5	5·50, 0·23	21·8	21·0, 0·85	18,000	
John Arnold No. 37	6	6·9	10·2	3·66	2·79:1	0·8	12·0	4·90, 0·27	17·3	23·6, 0·85	18,000	
John Arnold No. 21/68	8	8·8	14·4	4·60	3·13:1	1·1	11·0	5·82, 0·30	24·0	28·5, 1·0	18,000	
John Arnold and Son No. 125/225	32	7·7	12·5	4·00	3·13:1	1·0	14·5	5·50, 0·23	20·4	20·5, 2·75	18,000	
John Arnold and Son No. 186/487	35	6·6	10·8	3·42	3·16:1	0·8	12·0	4·60, 0·24	17·65	19·8, 2·0	18,000	
John Arnold and Son No. 298/599	36	6·8	11·0	3·35	3·28:1	0·96	12·0	4·70, 0·23	17·5	23·6, 2·7	18,000	
John Arnold and Son No. 358/659	37	6·75	11·0	3·58	3·07:1	0·9	12·0	4·72, 0·22	17·4	25·0, 2·3	18,000	
John Arnold and Son No. 17/1017	38	7·1	10·4	4·41	2·36:1	1·3	11·5	5·60, 0·22	17·7	21·0, 2·2	18,000	
John Roger Arnold No. 1761	40	6·7	10·8	3·60	3·0:1	1·1	11·5	5·20, 0·22	17·0	18·9, 2·55	18,000	
John Roger Arnold No. 1831	41	7·0	10·8	3·79	2·85:1	1·0	11·5	4·67, 0·22	17·5	19·8, 2·40	18,000	
John Roger Arnold No. 1962	45	7·1	10·4	4·37	2·38:1	0·8	12·5	4·65, 0·25	17·8	18·3, 1·71	19,200	
John Roger Arnold No. 1975	44	7·0	10·6	4·17	2·54:1	0·9	12·0	5·20, 0·22	17·8	18·3, 2·6	18,000	
John Roger Arnold No. 1984	46	7·6	11·3	4·60	2·46:1	1·1	13·0	5·50, 0·24	18·9	20·8, 2·62	18,000	
John Roger Arnold No. 2014	47	7·8	11·6	4·60	2·52:1	1·1	12·5	5·20, 0·24	18·5	20·3, 2·6	18,000	
John Roger Arnold No. 2162	49	8·0	11·4	4·86	2·34:1	1·1	10·5	5·20, 0·23	19·0	19·5, 2·6	19,200	
John Roger Arnold No. 2175	50	7·0	10·8	3·72	2·90:1	0·9	10·0	4·15, 0·21	18·0	17·0, 1·23	21,600	
John Roger Arnold No. 3580	48	6·3	damaged	3·69	—	0·9	broken	4·28, 0·23	17·3	17·3, 1·5	19,200	
John Roger Arnold No. 3772	51	7·0	10·8	4·14	2·61:1	0·9	9·0	4·70, 0·21	17·2	16·5, 1·9	19,200	
Richard Attenborough No. 3051	115	4·93	5·10	2·86	1·78:1	0·79	6·00	3·80, 0·24	17·0	21·0, 1·0	18,000	Twin barrels
Ward J. Baird No. 1734	90	7·5	10·2	5·35	1·91:1	1·05	9·5	3·70, 0·25	17·8	20·2, 2·1	17,485$\frac{5}{7}$	
Barwise and Sons No. 5414	88	6·2	8·60	4·45	1·93:1	0·7	—	4·70, 0·20	18·0	16·8, 1·65	18,000	
Barwise and Sons No. 7350	95	6·2	8·50	4·22	2·0:1	1·0	11·0	4·35, 0·25	19·4	18·0, 1·52	18,000	
Hilaire Basserean No. 316	11	7·16	10·6	4·0	2·65:1	0·64	9·58	2·48, 0·18	18·0	18·6, 1·10	17,554·285	
John Bennett No. 15425	106	5·5	7·50	4·00	1·88:1	0·95	9·0	2·75, 0·23	15·6	15·7, 1·94	18,000	
Breguet et Fils No. 4216	89	7·5	10·2	5·27	1·94:1	0·90	11·5	5·0, 0·23	19·8	25·5, 3·5	18,000	

II Pocket Chronometers with Detent Escapements (dimensions in mm) (*cont.*)

	Catalogue no.	Centre distance: Balance/Escape wheel	Escape wheel diam. E (No. of teeth if not 15)	Impulse roller diam. I	Ratio E:I	Ratios to tip of discharge roller (approx.)	Length of detent to point of flexure (approx.)	Mainspring: height, thickness	Barrel: internal diam.	Balance: diam. height	Train: beats/hour	Notes
Breguet et Fils No. 4652	83	6·6	10·0	4·1	2·44:1	0·9	11·5	5·74, 0·18	24·0	20·15, 2·31	18,000	Two tapered main springs
Arnold/Breguet No. 11/169	176	6·75	11·2$^{(18)}$	3·07	3·65:1	0·9	10·5	6·08, 0·22	21·5	19·9, 1·33	21,600	
Brockbank No. 383	147	8·40	11·6	5·55	2·09:1	1·4	20·0	6·95, 0·25	24·4	25·2, 1·7	18,000	
Brockbank No. 518	150	6·70	9·4	4·41	2·12:1	1·1	13·0	4·3, 0·26	19·4	17·4, 1·24	14,400	
Brockbank No. 919	72	7·4	10·8$^{(12)}$	4·86	2·22:1	1·28	12·0	4·10, 0·21	17·0	21·0, 0·58	14,400	
Brockbank No. 4302	149	6·40	9·0	3·93	2·26:1	1·0	14·0	3·88, 0·23	17·7	20·5, 1·25	17·485$\frac{5}{7}$	
Carley and Clemence No. 51619	182	5·5	7·2	3·96	1·82:1	0·8	6·4	4·2, 0·20	19·3	15·4, 1·82	18,000	
W. B. Clarke	94	7·0	10·0	4·25	2·35:1	1·0	10·5	4·80, 0·24	18·7	18·2, 1·73	18,000	
James Ferguson Cole No. s.x.	15	8·8	12·2	6·04	2·02:1	1·4	10·5	4·0, 0·23	19·2	19·8, 1·43	18,000	
W. E. Cribb No. 3726	102	6·5	9·0	4·55	1·98:1	0·9	broken	4·5, 0·24	18·4	18·2, 1·78	18,000	
E. J. Dent No. 5727	97	6·0	8·40	4·11	2·05:1	1·0	broken	2·55, 0·23	16·9	15·8, 1·77	18,000	
E. J. Dent No. 10215	101	6·0	8·60	3·83	2·25:1	0·93	10·0	2·15, 0·22	16·7	15·4, 1·78	18,000	
Duchemin No. E 184	18	6·64	9·14	2·40	3·8:1	0·81	6·30	5·3, 0·60	20·78	21·2, 1·2	7,200	
Thomas Earnshaw (Tomlin 1400)	57	7·00	9·70	4·23	2·3:1	1·12	8·50	4·26, 0·24	19·0	21·0, 0·85	18,000	
Thomas Earnshaw No. 457/2760	63	7·00	10·0	4·52	2·21:1	0·80	11·0	5·6, 0·23	19·8	19·2, 1·73	18,000	
Thomas Earnshaw No. 504/3163	59	6·6	9·5	4·47	2·12:1	0·80	11·0	4·9, 0·27	19·3	25·0, 0·55	18,000	
Thomas Earnshaw No. 506/2849	61	6·6	9·6	4·60	2·10:1	0·80	11·0	4·9, 0·24	18·3	25·5, 0·57	18,000	
Thomas Earnshaw No. 598/3041	62	6·7	replaced with Chinese Duplex					4·2, 0·25	18·2	25·15, 0·51	18,000	
Thomas Earnshaw No. 808/3816	64	6·6	9·2	Balance missing				5·45, 0·26	19·2	missing	18,000	
Thomas Earnshaw No. 866	65	7·0	9·6	4·86	1·97:1	0·80	11·0	4·70, 0·25	19·9	18·6, 1·65	18,000	
Thomas Earnshaw No. 876/3816	66	6·8	9·5	4·61	2·06:1	1·0	11·0	4·80, 0·24	19·5	18·6, 1·53	18,000	
George Edwards No. 605	117	6·4	8·4	4·60	1·83:1	1·04	9·0	3·75, 0·24	17·3	17·4, 1·62	18,000	
Ellicott No. 1021	79	7·0	9·5	4·93	1·93:1	1·2	10·5	4·90, 0·24	20·0	20·9, 1·93	18,000	
Ellicott No. 9920	84	6·6	9·2	4·37	2·1:1	0·90	11·5	5·20, 0·23	18·4	19·2, 2·2	18,000	
Ellicott No. 10078	85	5·7	8·0$^{(16)}$	3·84	2·09:1	0·80	11·0	4·25, 0·23	15·9	18·0, 1·58	18,000	
Josiah Emery No. 781	9	7·6	11·6	4·48	2·59:1	1·0	10·0	5·45, 0·20	16·3	19·9, 0·94	18,107$\frac{6}{7}$	
John Forest No. 5478	21	5·5	7·4	3·74	1·98:1	0·9	7·5	2·34, 0·19	17·6	14·4, 1·68	18,000	
Charles Frodsham No. 01380	105	6·25	8·6	4·41	1·95:1	0·70	11·0	2·34, 0·23	17·2	16·5, 1·91	18,000	
Charles Frodsham No. 02418	107	5·45	7·5	3·90	1·92:1	0·75	8·0	2·37, 0·25	16·0	17·4, 1·54	18,000	
Charles Frodsham No. 03503	104	5·1	6·8	3·47	1·96:1	0·75	—	2·01, 0·22	14·0	16·0, 1·49	18,000	

Charles Frodsham No. 8645	111	4·5	6·0	3·32	1·81:1	0·70	6·0	2·00, 0·20	14·5	15·5, 1·58	18,000	
Frodsham and Son No. 6950	108	5·75	7·8	4·09	1·91:1	0·70	8·0	2·3, 0·23	14·5	17·5, 1·38	18,000	
H. Golay No. 2766	100	7·2	10·0	5·90	1·70:1	1·35	11·2	5·55, 0·22	20·6	19·0, 1·63	18,000	
John Grant No. 2444	52	6·75	10·0	3·91	2·56:1	1·0	10·5	4·47, 0·23	16·8	20·0, 1·47	16,875	
Charles Haley	76	6·2	8·8	4·11	2·14:1	1·1	10·0	4·75, 0·20	17·9	17·8, 2·55	18,000	
Charles Haley	54	7·4	10·5	4·76	2·2:1	1·0	12·0	4·60, 0·26	19·6	19·6, 2·47	18,000	
C. Hanson No. 28	160	4·92	7·17	2·94	2·4:1	0·69	1·4	2·36, 0·25	15·5	16·0, 0·76	18,000	
Hunt and Roskell No. 10514	177	7·0	9·6	4·87	1·97:1	0·95	8·0	6·25, 0·27	20·8	18·7, 2·02	21,600	
Jules Jürgensen No. 12422	22	5·9	8·2	4·07	2·0:1	1·0	9·5	2·76, 0·20	18·2	20·0, 1·6	18,000	
Urban Jürgensen No. 424	56	7·9	11·6	5·04	2·3:1	1·0	10·0	4·95, 0·21	18·8	19·5, 2·3	16,200	
M. B. Lee and Son No. 3334	116	5·95	8·0	4·14	1·94:1	0·7	11·5	2·68, 0·27	15·8	18·5, 1·4	18,000	
James McCabe No. 10254	98	6·5	9·0	4·68	1·92:1	1·0	10·5	4·5, 0·21	17·5	23·5, 2·07	18,000	
Anthony Measure No. 1043	86	6·8	10·4	3·66	2·82:1	1·2	Broken	—	—	21·0, 2·0	15,428$\frac{2}{7}$	Balance not original
R. and H. Molyneux No. 3004	96	6·4	8·6	4·5	1·19:1	0·95	11·0	4·56, 0·22	18·3	18·0, 2·35	18,000	
George E. Mylne No. 64/5408	103	5·8	8·0	4·10	1·95:1	0·80	10·0	2·83, 0·23	15·2	18·0, 1·8	18,000	
Charles Nephew No. 57/1999	28	5·3	7·4	3·45	2·15:1	1·0	8·0	2·86, 0·20	16·3	16·2, 1·26	18,000	
P. Norris No. 5421	23	6·7	9·0	4·71	1·91:1	0·8	12·5	2·60, 0·24	16·7	16·8, 1·79	18,000	
Parkinson No. 574	93	5·52	7·33	4·31	1·7:1	0·94	9·50	4·69, 0·23	17·0	19·8, 2·57	18,000	
Parkinson and Frodsham No. 4608	112	5·9	8·0	4·22	1·90:1	0·93	9·0	2·75, 0·25	15·0	15·5, 1·77	18,000	
Pellaton No. 3009	181	5·0	6·8	3·65	1·86:1	0·73	7·8	2·84, 0·19	17·5	17·0, 1·20	21,600	
Pennington No. 426	78	6·5	9·6(18)	3·65	2·7:1	0·95	11·0	4·76, 0·21	16·7	23·0, 2·0	17,280	
Pennington No. 130/596	77	7·6	10·8	4·95	2·18:1	1·2	11·0	5·32, 0·22	18·5	24·2, 2·42	18,000	
Thomas Percival No. 815	53	7·4	11·5	4·17	2·76:1	0·87	14·0	4·94, 0·25	18·2	22·0, 2·0	17,828$\frac{4}{7}$	
Perigal and Brown No. 3020	55	7·4	12·0	3·52	3·42:1	1·2	12·5	4·34, 0·28	21·5	22·0, 1·92	18,000	
William Pickman No. 3165	80	7·0	10·0	4·70	2·13:1	0·9	12·0	4·80, 0·24	20·5	25·0, 2·2	18,000	
Albert H. Potter No. 62	30	6·1	8·2	4·12	2·1:1	1·6	9·0	3·00, 0·18	18·3	16·8, 2·44	18,000	
Thomas Pritchard No. 1859	154	6·3	9·8	3·5	2·8:1	0·9	4·0	2·45, 0·25	16·3	17·5, 1·1	18,000	
Reid	175	6·6	9·0	4·48	2·0:1	1·0	10·0	4·30, 0·26	19·0	18·2, 2·3	18,000	
Robert Roskell No. 5262	67	6·6	9·5	4·40	2·16:1	0·9	11·0	4·50, 0·24	19·2	24·4, 0·62	18,000	
Ami Sandoz and Son No. 90964	29	5·4	7·5	3·72	2·02:1	0·83	8·7	3·30, 0·19	18·2	18·0, 1·60	18,000	
Stephenson and Farrow No. 1073	68	6·6	9·0	4·52	1·99:1	0·94	11·0	5·50, 0·23	19·5	18·4, 2·9	18,000	
Charles Suchy et Fils No. 26403	178	5·0	7·0	3·30	2·12:1	1·0	4·5	2·80, 0·23	16·9	15·1, 1·38	18,000	
Alexander Watkins No. 4682	113	5·6	7·6	3·95	1·93:1	0·8	11·5	2·65, 0·22	14·5	13·3, 1·33	18,000	
Webster and Son No. 9572	114	4·5	6·0	3·33	1·8:1	0·8	7·5	2·15, 0·16	13·5	12·5, 1·23	18,000	

ABBREVIATED REFERENCES AND BIBLIOGRAPHY

Ac.Sc.
Academie des Sciences comptes rendus, Paris

AH
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CONCORDANCE

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GLOSSARY

Adjusted Term applied to a balance and spring on which work has been carried out towards eliminating timekeeping errors due to changes in temperature, position or state of the wind. On an unadjusted timepiece these problems are taken into account at the design stage and in the choice of materials, and the balance is carefully poised; but no further work, other than bringing to time, is carried out as regards the individual behaviour of the unadjusted timepiece as a result of the changes mentioned above.

Adjustable potance See *Potance*.

Affix A small bimetallic strip fitted to the main balance so as to bring about small changes in the moment of inertia of the balance. This may overcome middle temperature error or make the small corrections required to eliminate the residual errors of a 'self-compensating' balance spring and balance combination.

Airy's bar A fine adjustment arrangement, invented by Sir George Airy, for the temperature compensation of bimetallic balances. Two weights are lightly sprung against the inside of the balance rim and can be moved to increase or reduce the degree of compensation as they approach or withdraw from the free end of the cut rim. An adjunct which found little favour among chronometer makers.

All-or-nothing piece A piece in a repeating watch designed to prevent incorrect striking. If the slide is not pulled all the way round or the push-piece not fully depressed so as to ensure that the full number of blows are struck, the watch will not strike at all.

Amplitude The arc of swing of a balance measured from its rest position to the extreme of its swing. Thus if a balance has a total movement of 300° it has an amplitude of 150°.

Amplitude limiter See *Tripping*.

Anti-friction wheels Wheels arranged so that their outside diameters are the bearing surfaces of the pivots of wheels in the gear train. Thus the frictional restraint is reduced by a factor given as the ratio of the outside diameter of the anti-friction wheel to its pivot diameters.

Anti-magnetic Having the property of resisting the effects of an applied magnetic field, both during and after the application of the field (the latter being the more important). Without a precise definition the term means little, but is nevertheless often used.

Apparent solar time The time as given by the sun, i.e., as would be shown on a sundial. The Equation of Time is used to convert this to Mean Solar Time.

Arbor A shaft with bearings. If integral with a gear, often called a pinion.

Arc The arc of a balance is twice the amplitude often denoted as 'turns' by watchmakers. A balance 'doing one turn' has an arc of 360° and an amplitude of 180°.

Assortment A complete set of escapement parts.

Attachment The position that the inner termination of the balance-spring bears to the watch.

Auxiliary compensation An extra compensatory device fitted to a compensation balance to help to eliminate middle-temperature error.

Backlash The circumferential clearance between the meshing teeth of a pair of gears.

Backplate See *Front plate*.

Backslope On an arbor, the part that slopes from the shoulder to the next larger diameter. On a staff, the tapered portion below the balance seating and also the slopes behind the pivot-blending radius.

Balance A wheel with one, two, three or four spokes or 'arms', whose function is to control the rate of revolution of the gear train. Used without a spring in early timepieces, it was not until fitted with a spring that good timekeeping became possible. There are three main types of balance: (a) *plain*, where the rim may or may not be furnished with screws; (b) *cut*, where the rim is bimetallic and cut to form two, three or four circumferential strips; (c) *ovalising*, where the material is chosen for its unequal expansion in two directions at right-angles to one another or when either the arm or the rim is made of two differently expanding metals. The disposition of the screws and weights (i.e., by moving them nearer to or further away from the point at which the rim is anchored) enables the degree of compensation to be changed.

Balance-cock See *Cock*.

Balance screws The screws around the rim of the balance having all or any of the following functions: to poise the assembly, to bring it to time, to adjust the amount of temperature compensation in a compensation balance or to enhance the appearance.

Balance-spring The spring that, in conjunction with the balance, provides an oscillating assembly. It may be flat, spiral, helical, tapered helical or spherical, or a combination of certain of these; it may have an overcoil, and it may be made of many different materials.

Balance-spring stud The fixing for the outer end of the spring, or, in the case of a helical or spherical spring, the end that is fixed to the balance-cock or bridge. The fixing to the balance is known as the collet. This is normally mounted friction-tight on the balance-staff.

Balance staff The arbor on which the balance is mounted.

Balance stop A piece that can be moved to stop the balance.

Balance weights The weights on the rim of the balance.

Banking The part against which the lever in a lever escapement or the detent in the detent escapement rests once escapement action is over.

Banking pin A pin used to provide banking (q.v.).

Bar movement See *Lepine calibre*.

Barrel The box that contains the mainspring. A *hanging barrel* is one that is supported at one end only, usually the bridge, while the other end is in a clearance hole in the bottom plate. A *resting barrel* is also supported at one end only, usually by the plate.

Bascule escapement A loose term for the pivoted detent escapement.

Beat The escapement sound or 'tick'.

Beats per hour The number of to and fro movements of the balance per hour.

Beetle hand The type of hour hand that vaguely resembles the shape of the stag beetle. Used with a 'poker' minute hand. (see below).

Bezel The rim holding the glass.

Bimetallic A laminate of two metals, in horology usually brass and steel but not invariably so.

Black polish A polish so perfect that when looked at from certain angles it appears jet black.

Blued steel Steel that has been hardened by heating to a red heat and quenching in water or oil and subsequently tempered to 590 °F (310 °C). If the tempering is conducted in an oxydising atmosphere the steel will be coloured a rich blue.

Bolt and shutter A maintaining device with a shutter that covers the winding square. On being moved aside so that winding may occur, it at the same time brings a raised lever into mesh with a wheel in the going train; this keeps the train moving until the shutter once more covers the winding square.

Bombé jewel A jewel with a curved face against the pivot shoulder, thus reducing frictional losses and enhancing oil retention properties.

Boot A piece substituted for one of the two curb pins that can be turned so that a projection at its lower end passes beneath the balance spring and the other curb pin, so preventing the balance spring from escaping.

Bottom plate See *Top plate*.

Bouchon A brass or nickel bush used as a bearing for pivots.

Bow The loop at the top of a watch by means of which it can be lifted or attached to an albert, chain, chatelaine, etc.

Brace A piece designed to tend to hold the outer turn of the mainspring against the inner wall of the barrel, which helps to separate the mainspring coils thus reducing losses due to the adjacent coils rubbing.

Breguet hands The moon hands much used by A. L. Breguet. These hands tended to be more delicate than those used before Breguet introduced his new look.

Breguet key See *Tipsy key*.

Breguet spring A flat spiral spring with the last turn raised from the body of the spring and formed into a terminal curve that can be shaped to reduce positional and isochronal errors.

Brevet The French equivalent of 'Patented'.

Bride See *Brace*.

Bridge See *Cock*.

Bulls-eye glass A domed glass with a flat ground in the middle.

Bush See *Bouchon*. Also, the act of bushing a piece to correct a worn hole or to lengthen the bearing surface.

Cadrature The work beneath the dial.

Calibre The type of a watch, often including the size. It is really the briefest specification of the movement.

Cam A piece which is so shaped that when rotated it can move another piece in a controlled manner. The shaping may be on the edge of the cam or on its face.

Cannon pinion The part of the motion work mounted on the centre arbor and able to move relative to it during hand setting. It meshes with the minute wheel in many designs.

Cap jewel An endstone.

Capped movement A movement with a dust cap.

Carriage The piece in a tourbillon that rotates and contains the escapement.

Centre seconds Term describing a watch with the seconds hand at its centre. In modern watches also called *sweep seconds*.

Centre wheel and pinion The wheel and pinion at the centre of the watch; it usually rotates once an hour.

Champlevé An area of metal hollowed out usually to take enamel.

Chapters The hour numerals or marks on a dial. The ring on which the chapters lie is called the *chapter ring*. This may also have the minutes, and possibly another hour ring with quarter divisions.

Chasing Engraving in relief.

Chronograph A watch with a centre seconds hand that can be started, stopped and returned to zero at will. Also usually provided with a minute counter and sometimes an hour counter to show how long the hands have been in operation. All these hands are returned to zero together. See also *Split seconds*.

Chronometer In England, a watch or marine timepiece that has a detent escapement (although the word chronometer was used before this escapement came into use). Unfortunately the word is used by the French and Swiss to mean any watch that has obtained an official rating certificate, which can result in confusion.

Cock A supporting piece with a foot at one end only. If it has a foot at both ends it is called a bridge.

Collet A ring-shaped piece often associated in watches with, for instance, a hand, a balance spring or a wheel.

Compensated Taken to mean temperature compensated. The balance and balance spring are so constructed that over a certain range of temperatures the errors due to dimensional changes and changes in stiffness of the spring are reduced or virtually eliminated. A *compensated balance* is usually taken to be one that has to provide all the compensation required, but it can also be a balance that only has to provide the residual compensation for the so-called self-compensating balance spring.

Compensation curb A bimetallic strip that carries the curb pins and moves them to attempt to compensate for errors that would otherwise occur with a change in temperature.

Compensation screws Screws that can be moved along the balance and distributed to provide proper compensation, in conjunction with the movements of the balance rim. Weights that provide this facility are known as *compensation weights*.

Complicated work Term usually describing additions to the timepiece other than striking work, e.g. calendar work, phases of the moon, equation of time, etc.

Cone pivot A pivot shaped like a cone. Nowadays used in cheaper watches, but first widely used by A. L. Breguet.

Conical pivot The normal balance pivot, which is not in fact conical at all, but has a parallel portion with a radiused end and is blended into the next diameter of the staff with a curve.

Constant force escapement A special escapement with subsidiary spring (in portable timepieces) providing motive power. This is wound at frequent intervals, so the force at the escapement is virtually independent of fluctuations due to the imperfections of the gear train and the variations in the main motive force.

Consular case Usually understood to be a double-bottom case, of which the inner dome does not open. The movement is hinged and can be lifted out of the case front. See also *Double-bottom case*.

Contrate wheel A wheel that transmits motion from one arbor to another lying at right angles to it; the teeth, instead of projecting from the periphery, stand out from the face of the wheel.

Conversion An escapement substituted for the original: generally a lever escapement supplants a verge.

Coqueret A steel endplate mainly found in French watches after 1735. Screwed to the balance-cock, it provides the end bearing for the top pivot of the balance. By 1770 it was in general use but was then gradually supplanted by a jewel bearing, as was the English practice.

Counterpoised pallets Pallets having an appendage designed to help poise them.

Crank level escapement A form of lever escapement invented by Massey of Liverpool in which impulse is conveyed to the balance through what is really a single gear tooth. The notch in the end of the lever is in the form of a gap between two gear teeth, and the projection on the roller is made as a single-leaf pinion.

Crank roller See above.

Crescent or **passing hollow** The clearance cut into the roller of a lever escapement for the passage of the dart or guard pin.

Curb pins or **index pins** The pins embracing the balance spring that, when moved along it, effect regulation.

Cut balance See *Compensation balance*, although not all compensation balances are cut: some modern balances merely have affixes or become oval to effect compensation.

Cuvette A hinged and sprung inside cover designed to protect the movement of a watch, often of brass, even in good quality gold cases. Used on Continental watches and often engraved with maker's name, directions of winding, hand setting, number of jewels, type of escapement, etc.

Cycloidal curves The forms of gear teeth are based on two types of curves, the *cycloid* and the *involute*. A cycloid is the curve traced by a point on the circumference of a circle when the circle rolls without slipping. Two variants of this curve are used in gearing, the *epicycloid* and the *hypercycloid*. In the epicycloid the circle rolls on the outside, and in the hypercycloid on the inside of another circle. Using these curves for the tooth form helps to give a uniform transmission of torque.

Daily rate The amount a watch varies each day from correct time.

Dart Another name for the guard pin (q.v.), from its shape on high-quality hand-finished English and Swiss watches. It was sometimes screwed in position.

Deaf piece A push-piece in a repeater that, when pressed, prevents the watch from striking by taking the hammer blow. By this means the blows can be felt instead of heard. Not only for the deaf, since there are occasions when the noise of repeating on bells or gongs is undesirable.

Deck watch A precision watch for use on ship when establishing its position. It is normally large (say 18–24 lignes) and is used to transfer the time from the ship's chronometer or other time standard to the position where sightings are made on deck. Also used instead of a chronometer where vibration would otherwise be too severe for a normal size marine chronometer.

Depth The degree of intersection of two parts that work together, such as gear wheels or escapement parts.

Detached escapement An escapement that is not in contact with the balance except when unlocking, impulse or run to banking is occurring. Thus the lever and chronometer escapement are detached whilst the duplex, cylinder and verge are not.

Detent A loose term for a stop piece, generally confined nowadays to the detent of a chronometer escapement, but also to the fusee detent and the warning detent in striking.

Detent escapement Another name for the chronometer escapement (pivoted or spring detent).

Dial plate The plate to which the dial is fixed. Also known as the *front plate* or *pillar plate* where there is no separate plate carrying the dial only.

Differential up-and-down work Differential gearing employed for one form of up-and-down work on going-barrel watches. *Planar up-and-down work* employs spur gears.

Discharging pallet The pallet that effects unlocking in the chronometer escapement.

Divided lift In an English ratchet-tooth escapement all the lift, or impulse, is on the pallet, while in Sylvain Mairet's lever escapement for instance all the lift is given by the teeth of the escape wheel. But in the divided-lift escapement, lift is shared so that some is given by the wheel teeth and some by the pallets; this is the family to which the club-tooth lever escapement belongs.

Dog screw Screw with part of the head removed so that it can be turned to clear the piece on to which it is locked.

Dome The inside cover of a watch case which is like a second back.

Double-bottom case The form of watch case often used to house full-plate movements. The inner bottom or back is in one piece with the case band, and to inspect the movement this has to be swung out from the front of the case on its joint (or hinge). Before this can be done the bezel must be opened and the case catch released.

Double roller The type of roller used in the modern lever escapement, having one table carrying the ruby pin and another providing part of the safety-action arrangement.

Draw The characteristic of an escapement that keeps the lever or detent safely in the rest position once escapement action is over, despite any but the most severe of jolts and jars. The lever or detent is impelled against the stop using the force needed to recoil the escapement. The geometry of the pallet is such that in moving away from the stop, or 'banking', as it is called, the escape wheel is forced to move slightly backwards. Early makers, including Breguet, were reluctant to use this feature in the lever escapement since it seemed to contradict their belief that recoil escapements, and equally any recoil in any other escapement, were bad. In 1785 John Leroux was the first to introduce draw in the lever escapement, although it was present from the start in the spring detent chronometer, a feature of Arnold's particular design.

Drop The small free movement of the escape wheel necessary for its teeth to move from one pallet to the other. Without this, the geometry of the wheel would have to be perfect for the escapement to act without jamming, a manifestly impossible thing. However, the higher the quality, the less drop can be. The amount of drop is a question of design: in a good quality lever escapement the drop is usually 0·5°, which at a diameter of, say, 0·5 cm means a linear movement of about 0·02 mm. *Drop on* is the term used for the amount the chronometer escape wheel moves before it catches up with the impulse pallet on the roller.

In a cylinder escapement, drop is the amount the next wheel tooth moves forward on to or into the cylinder after impulse is completed.

Dumb repeater A repeater without bells or gongs where the hammers strike the case or a block mounted in the case.

Duplex escapement Commonly, an escapement with two sets of teeth. One set is long and pointed and provides the locking function by working with a small roller with a passing notch mounted on the balance staff; the second set stands up from the rim of the wheel and gives impulse to a pallet, sometimes jewelled, mounted on the balance staff.

Less commonly, two separate wheels may perform the two functions. As with the chronometer the impulse teeth do not need to be oiled, but oil is, however, required at the locking jewel. Although a frictional rest type, this escapement can, if not too worn, perform extremely well.

Dust cap A cap, usually fitted to the movements of watches hinged to the case, whose function is to help exclude dust. It is usually made of brass, though sometimes of silver, and is mainly found in English watches.

Ebauche The movement blank or rough movement. In the early nineteenth century this consisted of plates, cocks and bars with barrel, fusee, the wheels and assembly screws.

Elastic limit See *Hooke's Law.*

Endless screw See *Tangent screw.*

End shake Axial play. The clearance between the pivot shoulders and their bearing surfaces.

Endstone A thrust bearing made of jewel against which a pivot end bears.

Engine turned Decorated with a regular pattern machined with a special-purpose lathe. Even when the pattern consists of straight lines it is still described as engine turning.

English lever escapement The pointed-tooth variety of lever escapement where all the lift is on the pallets.

Entry pallet The pallet in the lever escapement where the escape-wheel teeth enter.

Epicylclic train A train of gears in which one gear travels around a fixed gear such as is found in tourbillons, karrusels, and in some systems of up-and-down work (q.v.).

Epicycloid See *Cycloidal curves.*

Escapement The element in a timepiece that transforms the rotary motion of the gear train into the oscillatory motion required by the timekeeping element.

Escape wheel The wheel that gives impulse to the balance and spring, either directly or through an intermediate piece.

Figure plate Another name for the index dial used with a Tompion-type regulator.

Finger piece The piece used in conjunction with the star wheel of Geneva stop-work (q.v).

Finishing The work required to bring a watch from the ebauche state to the finished condition.

Fire gilding Technique of coating the article to be gilded with an amalgam of gold and mercury. The mercury is then driven off by heat to leave a strongly adhering film of gold.

Flirt A lever or device that causes a sudden movement. It is usually raised slowly by a cam and suddenly released, but may be under manual control.

Fly A governing device consisting of a vane fixed to a pinion which in sweeping through the air slows the rate of rotation of the train of which it is a part. Used in striking, repeating work and in remontoires and constant force escapements.

Fly-back hand A hand that automatically or manually flies back to a zero position or to coincide with another hand.

Fly spring The spring that opens the cover of a watch case when the lock is released.

Foot detent A detent in which the support foot is integral.

Fork The fork-shaped end of the lever in the lever escapement that contains the notch.

Fourth wheel The wheel that normally drives the escape pinion and often carries a seconds hand. This is a loosely used term.

Frame The main frame of a watch that supports and locates all the other parts.

Free-sprung Without an index (q.v.). Free-sprung balances have to be brought to time in the final stages by altering the movement of inertia of the balance. This is effected by removing, adding or altering screws, adding washers, and/or by means of the quarter screws.

Frictional rest escapement An escapement that is always in contact with the balance.

Friction wheels See *Anti-friction wheels.*

Frosted Having a matt finish with the appearance that the term suggests.

Full-plate Term used to describe a watch in which all parts but the balance are located between two plates.

Fusee A grooved and tapered pulley which, when properly made, evens out the torque output from the mainspring. When the mainspring is fully wound the fusee is pulled on a smaller diameter than when it is run down. The best watches have their fusees matched to their individual mainsprings.

In a *reversed fusee* the normal planting of the fusee is reversed. The purpose is to put more of the pivot thrust resulting from the pull of the chain on to the fusee pivots rather than the centre pivots.

Fusee barrel The type of barrel used in conjunction with a fusee. It has no teeth, the great wheel being mounted on the fusee.

Fusee chain The chain that connects the barrel to the fusee. The making of fusee chains soon became a separate trade: the chain was invented *c.* 1635 and by 1680 was virtually universally used instead of gut in watches.

Fusee iron The piece fitted to the movement plate that acts as the stop by intercepting the fusee beak when the mainspring is finally wound. The position of the chain on the fusee dictates when the iron is moved into the path of the beak.

Gathering pallet The pallet that gathers up the rack tooth by tooth whilst striking occurs.

Gimbals The supports system designed to keep a timekeeper horizontal regardless of the attitude of its case.

Going barrel The barrel carrying the great wheel (q.v.) on its periphery or mounted on its arbor.

Going fusee A fusee with maintaining power.

Going train The train concerned with the timekeeping part of the watch as opposed, for example, to the striking or repeating train.

Gold spring See *Passing spring*.

Gong Strip of steel, on which the hammers strike, usually circular in section and shaped to go round the outside of the watch plate. Invented by A. L. Breguet.

Great wheel The first and slowest moving wheel in the train. Attached to the barrel or the fusee.

Grey Parts 'in the grey' are not yet finished by polishing, but are at the preceding stage.

Guard pin The pin that is part of the safety action in the lever escapement. It is attached to the lever and is centrally disposed with respect to the notch.

Hairspring The common name for the balance spring. Also, a general term for fine springs not associated with a balance, as in an electrical meter for instance.

Half plate Term to describe a watch in which only the barrel centre and third wheels are under the same back plate.

Half-quarter repeater A repeating watch that sounds single blows for the hours, a double blow for each quarter past the hour and another single blow for every $7\frac{1}{2}$ minutes passed since the previous quarter.

Hand setting In early watches the hand was set by pushing it. Later, the square on which the hand was mounted was extended so that the hand could be set by a key. Eventually the hand was set by pulling out and turning the pendant button.

Heart piece The heart-shaped cam operated by a lever to return a hand to zero.

Helical spring a spring in the form of a helix. The ends are normally incurved so as to obtain more uniform dilation as the spring works.

Hole The bearing in which a pivot runs.

Hooke's Law The law stating that for a given material the relationship of stress to strain is a constant: stress is force per unit area and strain the extension per unit length. This is only true within the elastic limit of the material, that is, within which any deformity due to stress is resolved when the load is removed.

Horizontal positions The positions in which a watch is horizontal, i.e. dial up and dial down.

Horn The extensions to the notch ends that form part of the safety action in a lever escapement, also in a detent that extended part against which the passing spring rests.

Hour rack The rack that in falling on to the hour snail determines the number of hours to be struck.

Hour wheel The wheel on which the hour hand is mounted, usually on a pipe extension. The hour wheel normally rotates every 12 hours, but sometimes in 6 or 24 hours.

Hunter A watch case with a solid cover to the dial. On a *half hunter* the centre of the cover is pierced so as to show the middle part of the dial.

Impulse The force applied to the balance to make good the losses due to friction and the fanning of the air.

Impulse angle The angle through which the balance moves during impulse.

Impulse face The face through which impulse is transmitted.

Impulse pallet The pallet through which impulse is transmitted.

Impulse pin The pin through which impulse is transmitted.

Impulse roller The roller through which impulse is transmitted or which carries an impulse pin.

Independent seconds A watch with two trains, one of which carries a seconds hand that can be stopped and started at will and whose rate of revolution is controlled by the other train. The independent train also usually has its own minute and hour hands.

Index The piece carrying the *index pins*, the pins that embrace the balance spring and can be moved along it for regulation purposes.

Intermediate wheel and pinion A wheel and pinion lying between the great wheel and the centre wheel.

Isochronous Having the property of oscillating at a constant rate despite the amplitude of oscillation. An isochronous balance will perform long and short arcs in the same length of time.

Joint The hinge of a case. The *knuckles* are the individual tongues of the hinge; thus a five-knuckle joint has three projections on one part of the hinge and two on the other.

Jumper A spring or spring-controlled piece used to locate another piece.

Jumping seconds A hand that moves forward in one-second jumps despite the fact that the escapement moves forward at more frequent intervals.

Karrusel A watch with a revolving escapement. If it revolves in 6 minutes or fewer it is usually called a *tourbillon*.

Keyless watch A watch that can be wound and set without a separate key. Early keyless winding watches still needed a key for hand setting. See also *Rocking bar keyless work* and *Sliding pinion keyless work*.

Knuckles See *Joints*.

Lantern pinion A pinion whose leaves take the form of rollers or trundles or, latterly, wire pins. The pins are held between two circular plates or (more unusually) project from one plate only.

Lepine calibre A watch movement introduced by J. A. Lepine in about 1770, in which the top plate is replaced by bridges and cocks. Also called a *bar movement*.

Lever escapement Escapement where impulse is given through a lever interposed between the escape wheel and the balance. Invented by Thomas Mudge, it subsequently became the most widely used escapement in higher-quality watches.

Lever notch In a lever escapement, the opening at the end of the lever which works with the impulse pin.

Lift The travel of the lever during impulse.

Ligne One-twelfth of the old French inch, equivalent to 2·25 mm.

Locking The angle that the piece that is moved to unlock the escapement has to move before impulse begins (i.e. the angle required for safety of action of an escapement).

Mainspring The spring providing the driving power for the various trains in watches, going, repeating, etc.

Maintaining power A device for keeping a watch going when it is being wound where otherwise it would stop – as when it has a fusee. Harrison's maintaining power is most common but Arnold did fit Sun-and-Planet maintaining power in some of his early watches and chronometers.

Maltese Cross A wheel of that shape forming part of a Geneva stop-work (q.v.).

Massey lever escapement See *Crank lever escapement*.

Mean time The average of all the solar days in the year, used as the basis of civil time.

Middle temperature error The elasticity of a steel balance spring does not vary in the same way as does the moment of inertia of the balance when the temperature changes. The moment of inertia changes with the square of the temperature, whereas the elasticity of the balance spring changes linearly. By adjusting the mass and position of the compensation weights or screws, the errors of timekeeping consequent upon changes due to the balance can only be matched to errors produced on the spring at two temperatures. Between these the balance and spring will gain, whilst at other temperatures there will be a loss. This is called middle temperature error and can be overcome partially or completely in various ways (see Appendix).

Minute repeater A repeater that strikes the hours, the quarters and the minutes past the quarter.

Minute wheel and pinion See *Motion work*.

Moon hands See *Breguet hands*.

Motion work The gearing beneath the dial which causes the hour hand to revolve twelve times (or, unusually, 24 times) slower than the minute hand. It usually consists of the cannon pinion, hour wheel, minute wheel and pinion.

Movement The 'works' of a watch: that, is a watch without the case, hands, and dial. For *Rough movement*, see *Ebauche*.

Offset seconds Small seconds where the seconds hand is not at the dial centre, and therefore not concentric with the hour and minutes hands.

Oil sink A depression around a pivot hole to help retain oil and to make the amount that can be safely applied greater; surprisingly, not introduced until about 1715 by Henry Sully.

Open face Term describing a watch with a glazed front. A half hunter (q.v.) is not considered open face.

Oscillation A constant and repetitious sequence of events: a pendulum and balance oscillate continuously, providing that some source of energy is available to maintain the oscillations (that is, to make good the various losses in the oscillating system).

Overbanked Term normally used to indicate that the impulse jewel is not in the notch, so that it rests on the outside of the horns.

Overcoil The coil of the balance spring that is raised above the body of a flat spring and is then shaped to a particular form. Invented by A. L. Breguet.

Pair case The standard form of the case for English watches between the mid-17th century and the end of the 18th century and beyond. The inner case contains the movement and is protected in its turn by an outer case. The outer case often decorated in the style of the period, although later tended to be more plain; inner cases were frequently plain.

Pallet Specifically, the part through which the escape wheel impulses the balance. When this part is made of jewel it is called the *pallet stone*.

Parachute (Parechute) A shock protection device for the balance staff (q.v.) invented by A. L. Breguet. The balance endstones are not rigidly mounted but held by long, springy arms that give under shock. The earliest form of shock protection.

Passing hollow See *Crescent*.

Passing spring Spring allowing the discharging pallet (q.v.) to pass the detent (q.v.) in one direction without unlocking the detent. Also known as the *gold spring* (because it is usually made of gold).

Pedometer watch Either an early self-wound pocket watch whose self-winding weight oscillates at every step, or a watch and pedometer combined.

Pedometer wind See *Perpetual watch*.

Pendant The part on top of the watch to which the bow is fixed. Its form can help to date a watch: in later keyless watches the pendant carries the winding button, the winding stem passing through it.

Perpetual watch The English for *montre perpétuelle* or self-winding watch.

Pillar Watch component whose function is to locate, support and separate the plates or a plate, bridge or cock. The earliest pillars were of square section; later, about 1600, styles became diverse: Egyptian, tulip, pierced foliate, lyre-shaped, square section, baluster and then cylindrical.

Pillar plate One term for the plate nearest the dial to which the pillars are fixed.

Pillar wheel Cam controlling the motion of the chronograph levers. It has two sets of teeth: ratchet teeth used to index it, and contrate-type teeth for moving the levers.

Pinion Usually the driven wheel in watch work, normally with 12 to 6 leaves (or teeth), although some pinions in high-class work may have as many as 16 leaves.

Pitch The distance between teeth along the pitch line (i.e., circumferentially).

Pivot The bearing area of a rotating piece, not necessarily (though usually) at the end of the piece. Its diameter tends to be small to reduce friction.

Pivoted detent A chronometer detent supported by pivots, as opposed to a spring detent (q.v.).

Planar up-and-down work See *Differential up-and-down work*.

Planting The process of determining the position of mating parts and making the holes in which they run or that take the jewels that form the bearings.

Plates The main members of the watch: the frame that locates and supports all the other parts.

Poise If the poise of a balance is perfect it will in theory display no heavy point when supported on knife edges.

Pointed-tooth lever escapement See *Lever escapement*.

Poker hand The minute hand that usually matches the beetle hand, somewhat reminiscent of a poker.

Positional error A difference in rate that results from a change in position, whether dial up to dial down, between dial up and the vertical position pendant up, and so on.

Potance (Potence) A cock (q.v.) that lies between the plates.

Potance plate An old term for the back plate because in verge watches it carried the potance that supported the lower pivot of the verge.

Pump pendant A pendant with a push-piece passing through it, usually to operate repeating work.

Pulse piece A pin projecting through the case edge that is moved by the bell hammer so that repeating the watch can enable one to feel the hammer-blows instead of hearing them on the bell.

Push fit A fit such that two pieces can be pressed together to fix one piece within the other.

Quarter rack See *Hour rack*.

Quarter repeater A watch that can be made to strike the hours and the quarters.

Quarter screws The screws in a compensation balance that can be adjusted to alter the moment of inertia and/or the poise. Because they are set approximately 90° apart, they are called quarter screws. They are either made a close fit in the threaded hole in the balance or the balance rim is slit so that the hole may be closed slightly so as to give a springy grip (as in the Glashütte balance).

Rack Toothed segment. See *Hour rack*.

Rack tail The tail of the rack which on contacting the snail stops the rack from falling further and thus dictates the number of blows to be struck.

Ratchet wheel A wheel which, in conjunction with a click or ratchet, can move in one direction only, or such that some change in the position of the click must occur for it to move in the other direction.

Rate The amount by which a timekeeper varies from the time that it is intended to show. A timekeeper can have a large rate but still, providing it is uniform and predictable, be a perfect timekeeper.

Recoil The backward movement of an escape wheel during the normal escapement operation. All truly successful watch escapements have recoil, however small, as this is utilised to provide draw (q.v.). Many early escapements and even one late one – the cylinder – had no recoil. However, they were then either frictional rest escapements (q.v.) or not fully developed.

Red gold A red-coloured gold, usually 50% copper, 50% gold.

Regulator dial An index plate that covers and carries a gear that meshes with the segment of a larger gear carrying the curb pins which are moved by turning a square, this being integral with the index plate and its gear, with the winding key.

Remontoire (Remontoir) A constant force device placed in the train near to the balance. It supplies the power to maintain the balance and is rewound at short intervals by the main source of power. Thus the main variations due to the gear train and the running down of the mainspring are eliminated.

Remontoire escapement See *Constant force escapement*.

Repeat A watch repeats if one can make it strike at will.

Repeater There are many types of repeater: quarter, half-quarter, minute, five-minute and half-ten-minute. The watch is made to repeat by pressing on a plunger, operating a push-piece or pulling round a slide. The hammers may strike a bell or gongs or on a block, this latter being known as a *dumb repeater*. Repeating work was invented by Daniel Quare in the 1680s.

Resilient escapement A form of lever escapement (q.v.) in which, when banking occurs, the blow on the impulse pin (q.v.) is taken by a non-rigid part of the lever, or in which the escapement is so arranged that recoiling the escape wheel (q.v.) serves the same purpose.

Robin escapement A single-beat lever-chronometer escapement made by H. Robin in the 18th century. Locking takes place on the lever and the impulse is given direct by the escape wheel to the balance.

Rocking bar keyless work The rocking bar carries wheels both to wind the watch and to mesh with the motion work (q.v.). Rocking the bar takes the gears that wind the watch out of mesh and puts those that rotate the motion work into mesh.

Roller See *Impulse roller*.

Runners The gear train of a repeating mechanism.

Run to banking In a lever escapement, the extra movement of the lever needed above the bare movement required to allow the escapement action to occur. The extra movement is required for safe action.

Savonnette A watch with a front cover to protect the glass.

'Scape wheel See *Escape wheel*.

Secondary compensation Compensation that is additional to the main compensation and can correct small residual errors.

Seconds train A train so designed that one of its wheels rotates once a minute, and can therefore have a seconds hand mounted on it.

Seconds wheel and pinion The wheel and pinion in the train that rotates once a minute.

Secret signature Used by A. L. Breguet to protect himself against forgeries. Has to be looked for carefully and is usually near the XII on the dial. A few other makers subsequently adopted the idea.

Secret springs The fly and lock springs of a hunter case (q.v.).

Segment weight A type of weight that is slid along the arms of a compensation balance to adjust the amount of compensation. Called a segment weight because of the shape which is in section a truncated wedge.

Self-compensating spring Something of a misnomer, but nevertheless a convenient term for a spring with a small thermal coefficient of Young's modulus (q.v.) that can have its characteristics modified by the maker to compensate for changes in its own dimensions, its stiffness and the dimensions of the balance. For complete compensation there must still be some adjustable device attached to or designed into the balance.

Self-winding Term describing a watch that is able to wind itself through the movements of the wearer. See also *Perpetual watch*.

Set-up Since the bottom diameter of a fusee cannot be infinitely large, it cannot give the correct torque when the mainspring is run down. In practice the bottom diameter is determined by the size of the great wheel and the need for a maintaining ratchet (or winding ratchet in early watches). The mainspring must be set up to give both correct torque at this diameter and a torque that can be matched by a reasonable size of smallest diameter at the top of the fusee. Working out the shape of a fusee is a complex matter and is seldom done other than empirically or by virtue of experience. A really good match can only be achieved by adjusting the fusee once it is working with its spring.

Sidereal time Time as given by the stars.

Single-beat escapement An escapement such as the chronometer where impulse is given when the balance is travelling in one direction but not the other. This is usually considered to be a drawback in an escapement for use with portable timekeepers as it increases the liability of the watch to stop.

Single-plane escapement An escapement that works in one plane, as does a normal lever escapement.

Sliding-pinion keyless work Keyless work employing a castle wheel (i.e. one that has face ratchet teeth at one end and contrate teeth at the other). During normal operation the ratchet teeth mesh with matching teeth on the winding pinion. When the winding stem is pulled out the castle wheel moves so that the ratchet teeth separate and the contrate teeth mesh with a hand-set pinion.

Snail A cam-shaped piece, usually in striking work, which dictates the number of blows to be struck.

Solid banking Banking provided by part of the bottom plate as opposed to a pin.

Solar time Time as indicated by the sun, e.g. as on a sundial.

Spotting A method of finishing with a series of overlapping spots arranged in concentric circles or more usually in straight lines.

Split seconds A chronograph watch with two centre seconds hands that can be used to time two discrete events. One hand may be stopped, then, if one wishes, the second. When next the plunger is pressed either the second hand returns to its position over the first, or both may be returned to zero, or both may continue together.

Spring barrel A barrel containing a mainspring.

Spring detent The detent of a chronometer escapement that is supported and located by the spring that returns it to the locked position.

Standing barrel A barrel supported at its lower end only.

Star wheel A wheel with triangular teeth that can be indexed and is located by a jumper (q.v.). Usually carries the striking snail (q.v.).

Stones Jewels.

Steady pin A pin used to locate a part relative to another part.

Stick-slip friction The difference between the friction between surfaces when they are first caused to slip and that when they continue to slip.

Stop-work The arrangement fitted to a fusee (q.v.) or going barrel (q.v.) to limit the number of turns of winding. Always at the top end to prevent the spring being fully wound, and with going barrels usually limiting the number of turns by also stopping the barrel before the spring is unwound. A *Geneva stop-work* employs a Maltese Cross and a finger-piece.

Straight line lever A lever escapement in which the pivots of the balance, lever and escape wheel lie in a straight line. Almost invariably (there are exceptions) the layout of modern lever watches.

Stud The outer termination into which the spring is either pinned, clamped or latterly cemented. This is in turn screwed or clamped to the balance bridge or cock (q.v.).

Subsidiary seconds See *Offset seconds.*

Sugar tongs An early compensated curb-pin device shaped like latter-day washing tongs. Both blades of the tongs are bimetallic and carry one curb pin at their termination.

Sunk-seconds A seconds dial set below the level of the main dial.

Supplementary arc The arc that a balance describes over and above the minimum required for escapement action.

Sunrise piece A device fitted to the snails of repeaters (q.v.) to prevent incorrect striking just after the hour or just after each quarter.

Sweep seconds See *Centre seconds.*

Swiss lever escapement The term loosely used to indicate the club-tooth lever escapement to distinguish it from the English or ratchet-tooth lever escapement.

Table roller The roller of the lever escapement on which is mounted the impulse pin.

Tangent screw A worm used in conjunction with a worm wheel for setting up the barrel (see *Regulation*). About 1675 this worm was moved inside the plates; before this it was mounted on the top plate.

Temperature compensation Since most metals change dimensions with changes in temperature, some sort of compensation has to be carried out if the balance and spring are not to change their timekeeping characteristic when temperature changes occur.

Terminal curves Called incurves when discovered by J. Arnold, these were first applied to helical springs (q.v.) and helped to make the spring expand and contract uniformly. Subsequently applied by A. L. Breguet to flat spiral springs. The object in theory of the terminal curve is to keep the centre of gravity of the spring on the balance axis as the spring dilates and contracts. In fact, for close rating these curves are only the starting-point and normally need to be modified to achieve close positional rates. Also, the point of attachment of the inner end of the spring has to be controlled for best results.

Third wheel and pinion Normally the wheel and pinion next to centre wheel and pinion that in turn drives the fourth wheel and pinion.

Three-quarter plate The top plate of a three-quarter-plate watch covers the barrel and centre, third and fourth wheels, but not the escapement.

Timepiece A timekeeper that does not strike.

Timing in positions See *Adjusted.*

Timing screws See *Quarter screws.*

Timing nuts See *Quarter screws.*

Tinted gold Also called coloured gold. Gold can be produced in various colours according to the metals with which it is alloyed. See also *Red gold.*

Tipsy key A key designed by A. L. Breguet that can wind in one direction only; it freewheels in the other direction so that no damage can be done if attempts are made to wind in the wrong direction. Also called a *Breguet key.*

Tompion regulator See *Regulator dial.*

Top plate The plate on top if one considers that near the dial as the bottom plate; the preferred term is back plate.

Tourbillon A. L. Breguet patented his 'tourbillon regulator' in 1801. This was a carriage that revolved at one, four or six-minute intervals and carried the escapement complete. This nullified the vertical positional errors.

Torque A turning moment. It is calculated as force times distance and its units in horology are usually grams – centimetres.

Train The wheels and pinions used to connect the barrel to all the other moving parts in a watch. This may be the going train, the repeating train, the musical train, etc., according to its purpose.

Trial number A number arrived at by multiplying factors determined during trials in such a way as to indicate the excellence of the time-keeping performance.

Train count The number of teeth in the wheels and pinions (q.v.).

Trammels In a balance, restraining wires that prevent the overflexing of the balance rims should they be cut.

Tripping If the amplitude of the duplex or chronometer balance becomes too high the escapement can be unlocked a second time and a second tooth can escape during the one excursion of the balance. This is called tripping. Sometimes an *amplitude limiter* is included to prevent the amplitude building up to this dangerous extent.

Under-dial work The work that lies between dial plate and dial. Also called *cadrature*.

Up-and-down dial A dial showing the state of wind of the mainspring. Usually only found in higher-class work. See also *Differential* and *Planar up-and-down work*.

Vertical positions The positions when the balance is hanging vertically as opposed to being horizontal. The four quarter positions are usually designated pendant up, pendant right, pendant down and pendant left. The horizontal positions are dial up and dial down.

Volute balance spring The flat spiral spring.

Watch papers Originally used to protect the inner pair case from the inside of the back of the outer case, which is where they were placed. Towards the end of the 18th century they also served as advertisements and often carried sentimental rhymes or sometimes a table of the equation of time.

Winding button The serrated cylindrical or spherical piece that is rotated by the fingers to wind the watch or set hands.

Winding square The square on the barrel arbor or fusee by means of which the watch is wound. This square may be internal when the designer wishes to reduce the overall thickness of the watch.

Winding stem The shaft carrying the winding button. See *keyless winding*.

Wolf-tooth gearing Gearing which drives in one direction only may have this special tooth form, so-called because of its shape. Although commonly met with in keyless winding wheels, it has been used throughout the gear train in some rare watches.

Worm wheel See *Tangent screw*.

Young's modulus The ratio of stress to strain. See *Hooke's Law*.

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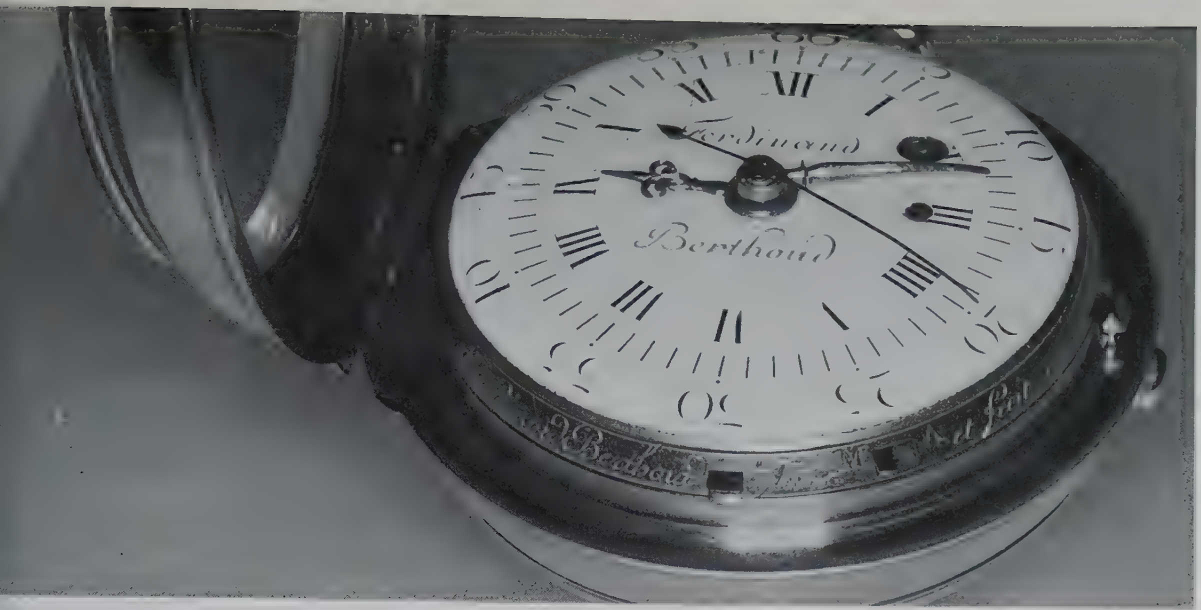
Plate I

a. Cat. no. I.
b. Cat. no. I.
c. Cat. no. I, under dial.
d. Cat. no. I, grid-iron.
e. Cat. no. I, grid-iron removed.


Ferdinand
Berthoud

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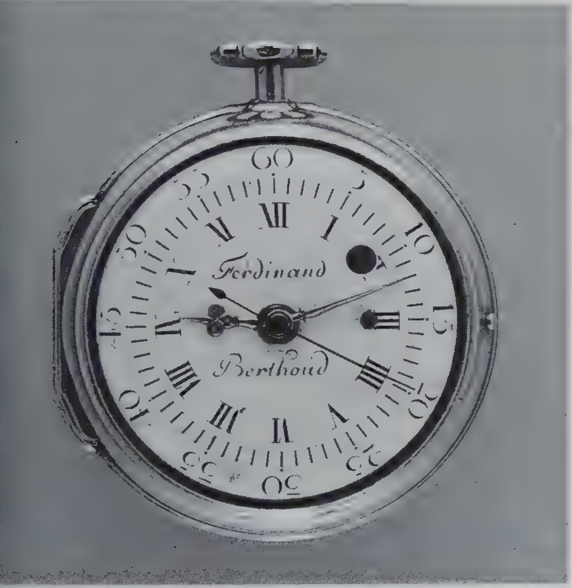
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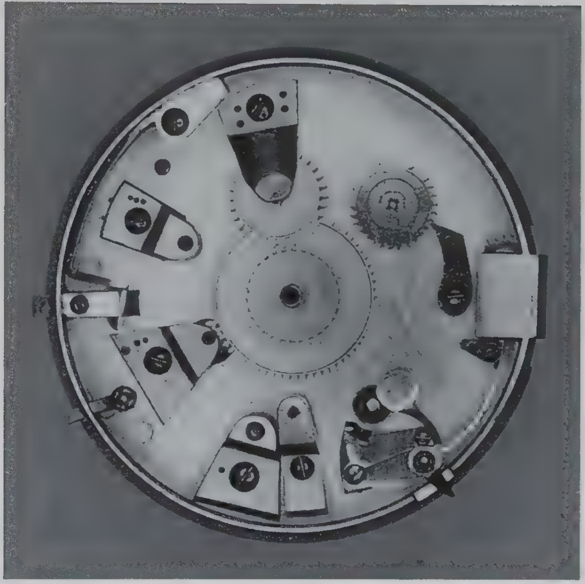

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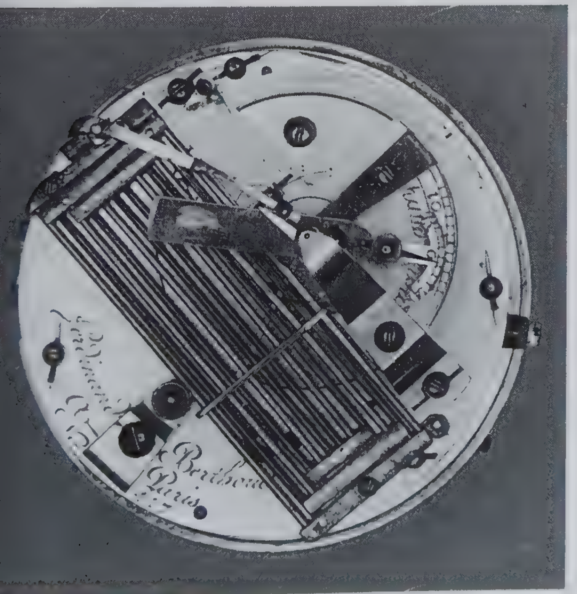
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Paris

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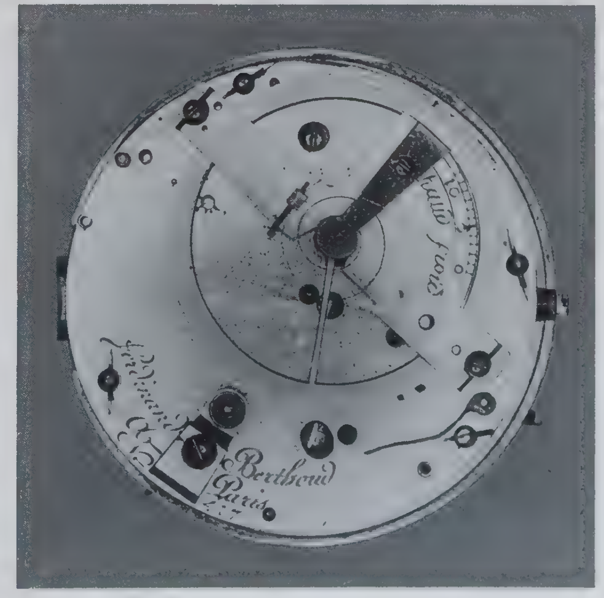
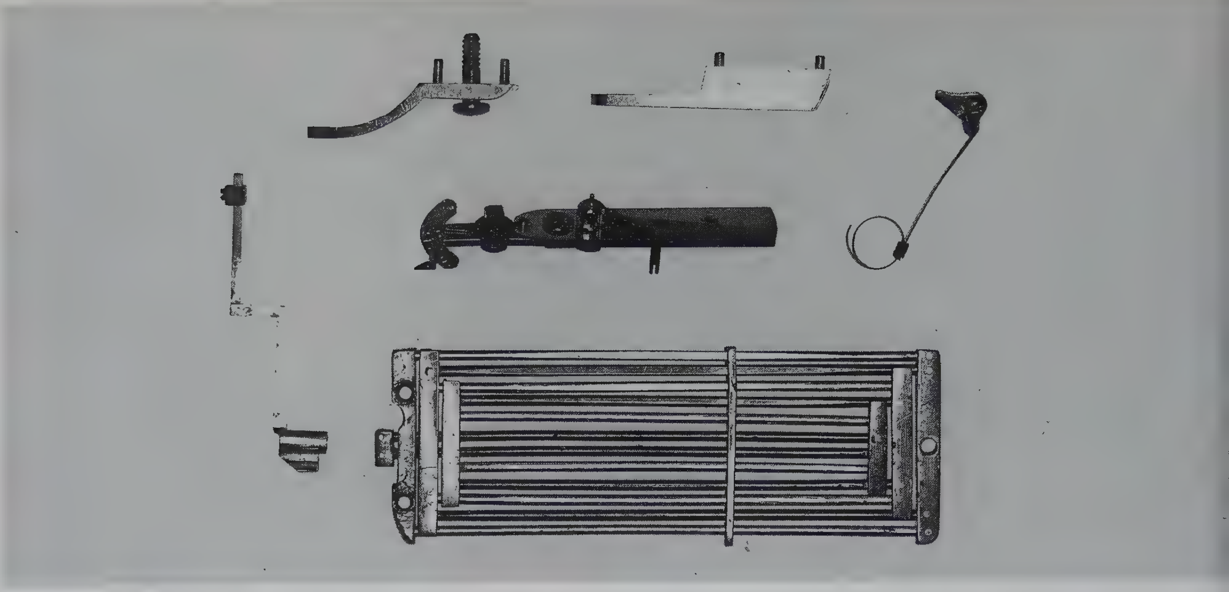

Berthoud
Paris

e

Plate 2

a. Cat. no. 1, grid-iron and associated parts.
b. Cat. no. 2.
c. Cat. no. 2, dust cover.
d. Cat. no. 2.
e. Cat. no. 2, under dial.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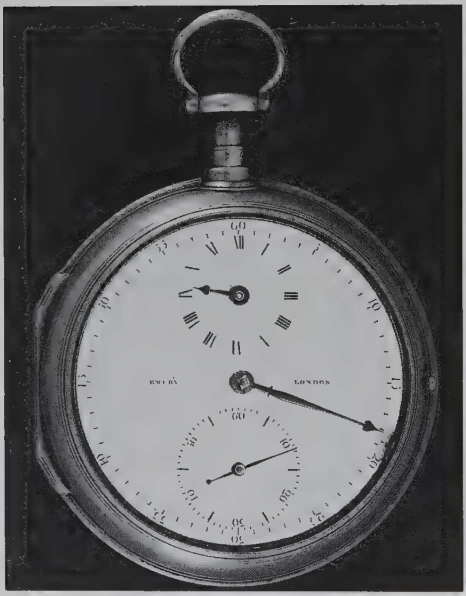
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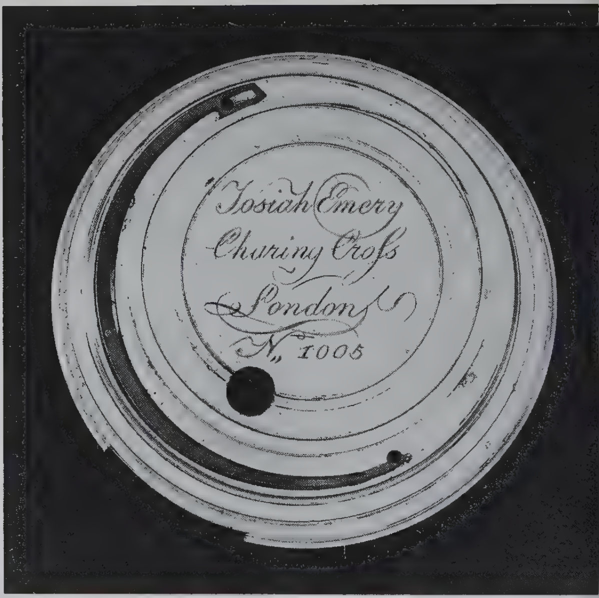
EMERY
LONDON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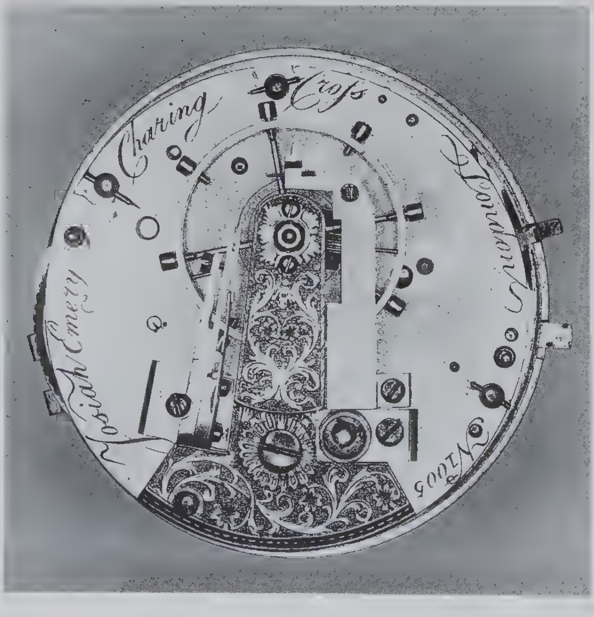
Josiah Emery
Charing Crofs
London
N,, 1005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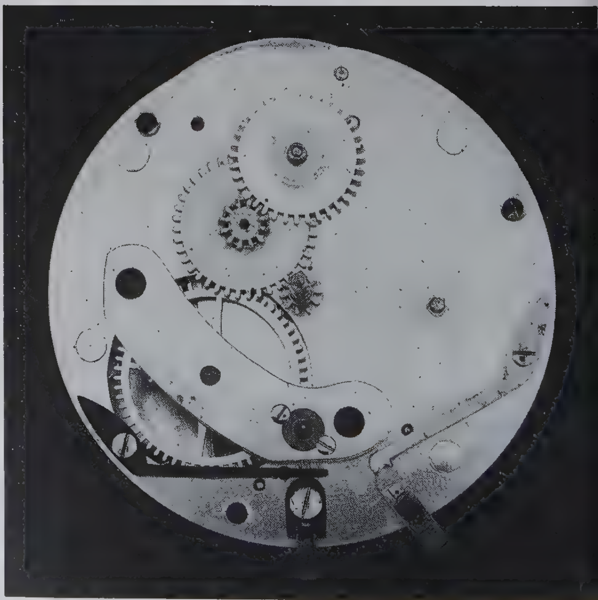
Charing Crofs
Josiah Emery
London
N1005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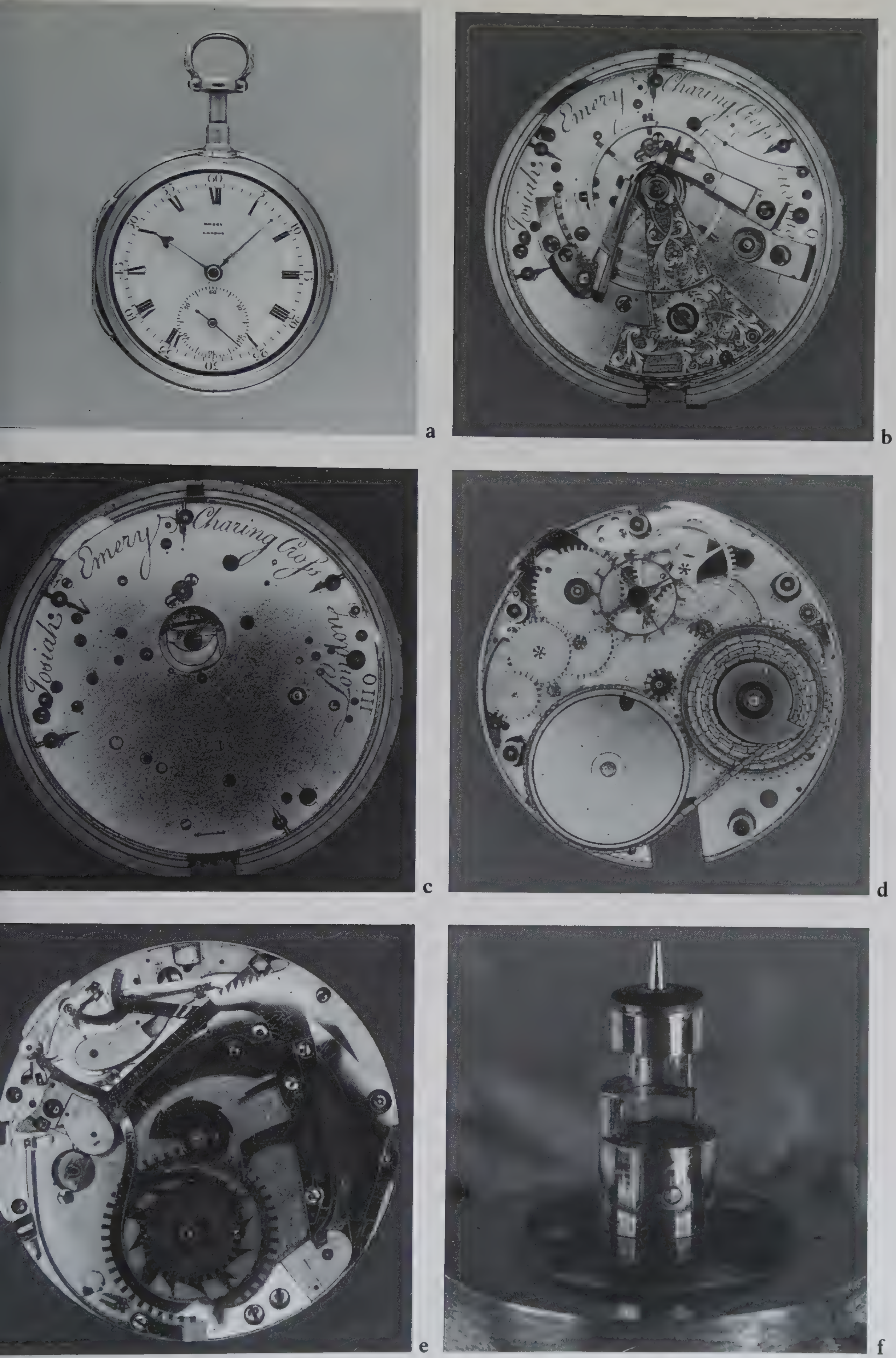
Josiah Emery Charing Cross
Josiah Emery Charing Cross London 1110
a
b
c
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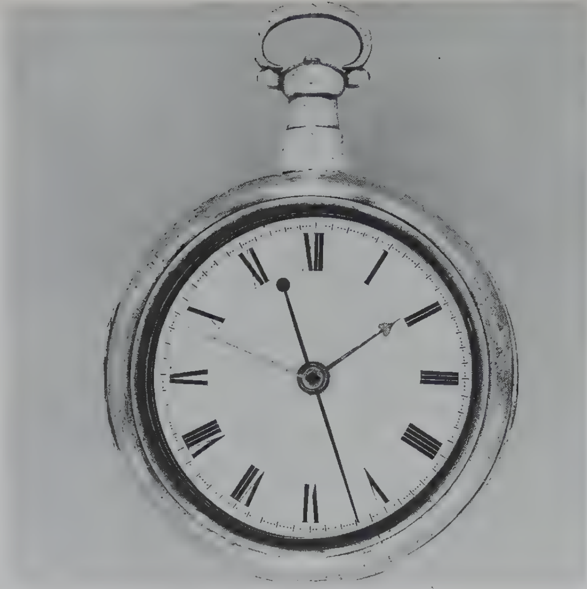
f

Plate 3

a. Cat. no. 3.
b. Cat. no. 3.
c. Cat. no. 3, backplate with parts removed.
d. Cat. no. 3, backplate removed.
e. Cat. no. 3, under dial.
f. Cat. no. 3, ruby cylinder.

Plate 4

a. Cat. no. 4.
b. Cat. no. 4.
c. Cat. no. 4, backplate removed.
d. Cat. no. 4.
e. Cat. no. 5.
f. Cat. no. 5, back of dial.



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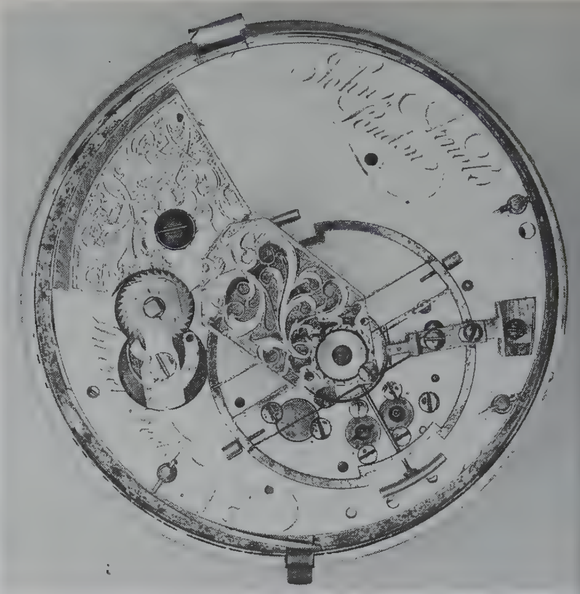
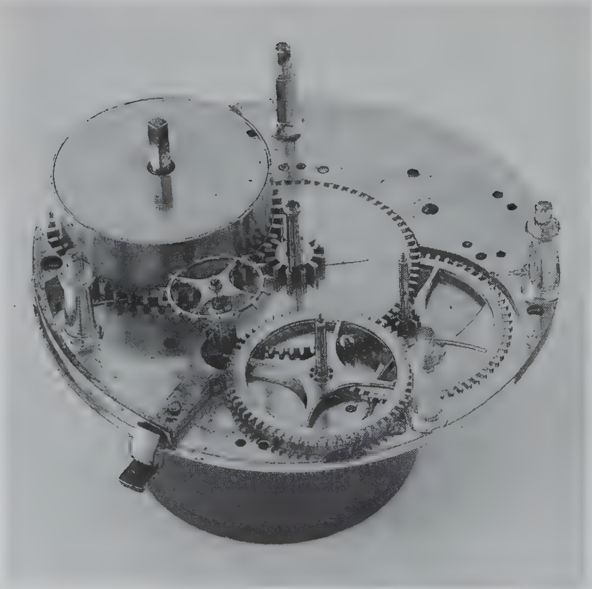

John Arnold
London

b



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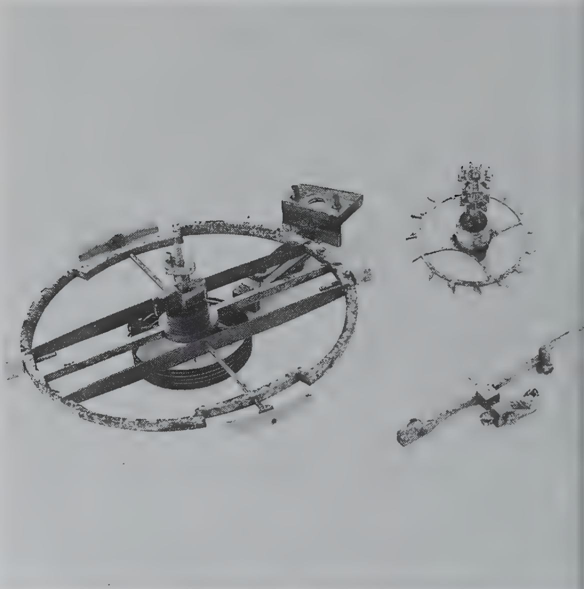

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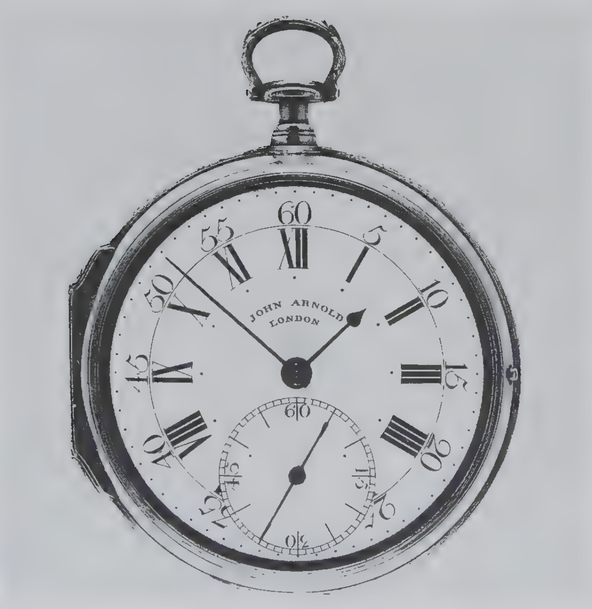
JOHN ARNOLD
LONDON

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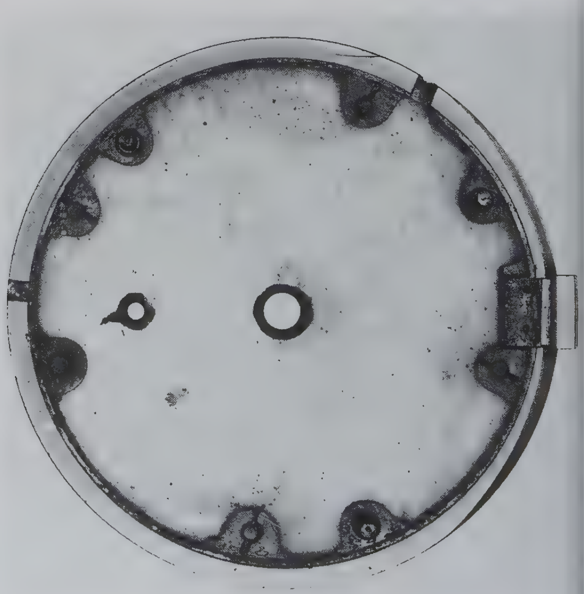
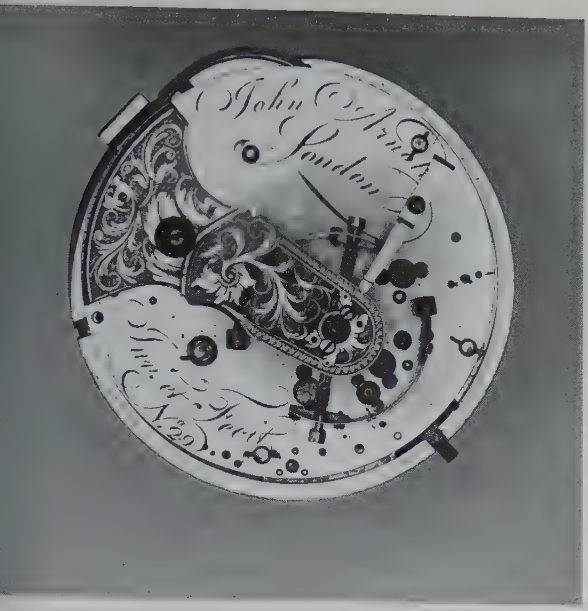


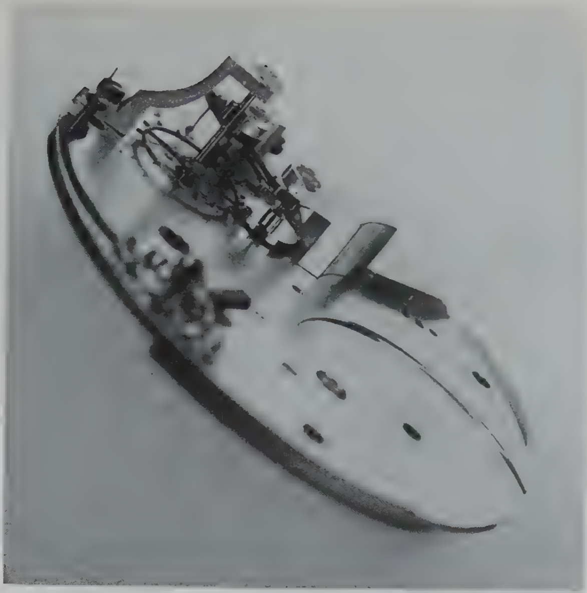
f

Plate 5

a. Cat. no. 5.
b. Cat. no. 5, escapement.
c. Cat. no. 5, under dial.
d. Cat. no. 6.
e. Cat. no. 6.
f. Cat. no. 6, under dial.


John Arn
London
Inv. et Fecit
N.29

a



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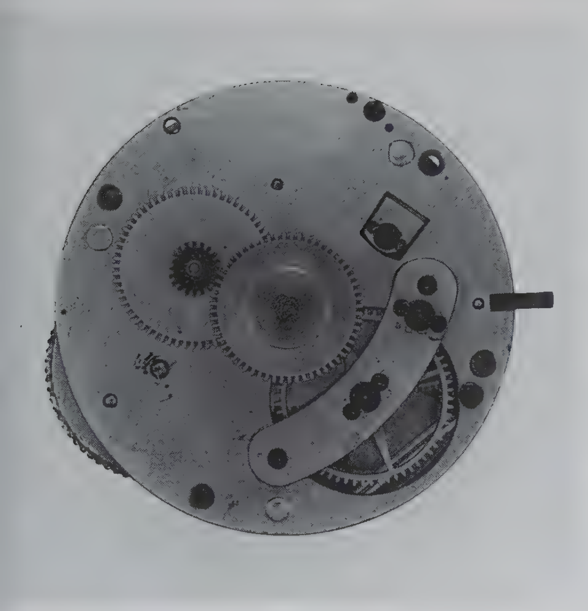

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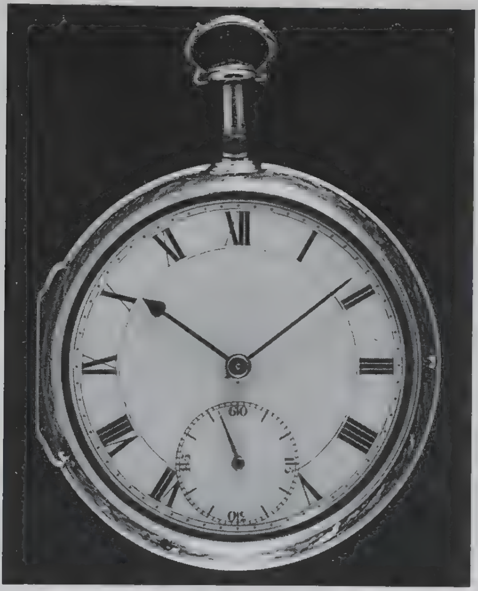

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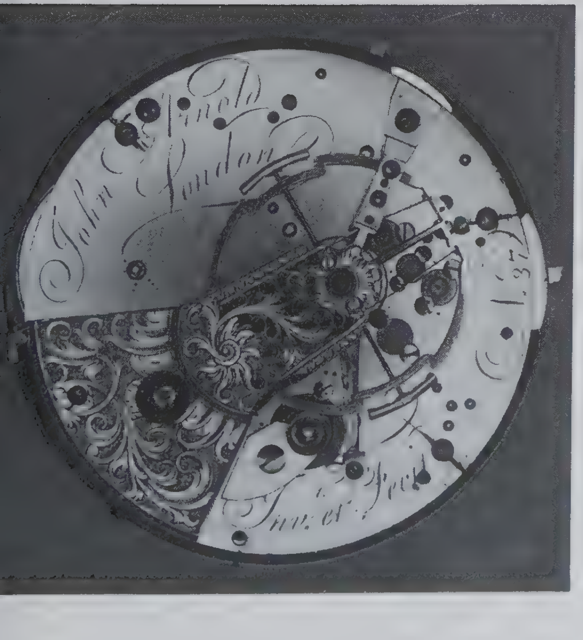
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London
Inv. et Fecit
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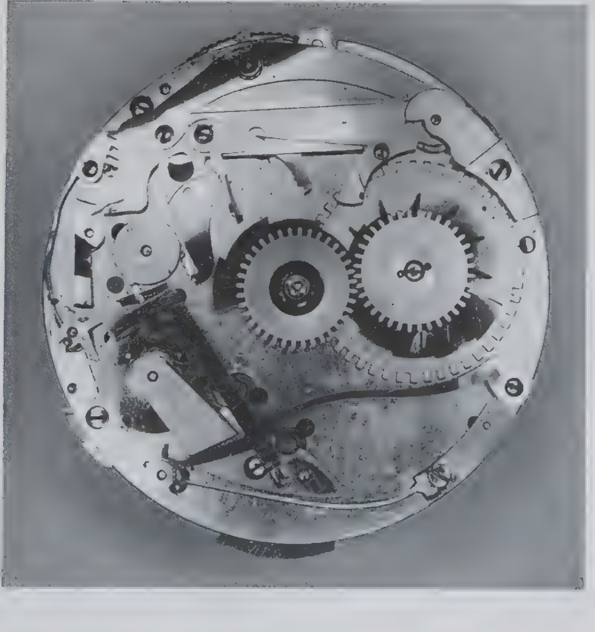
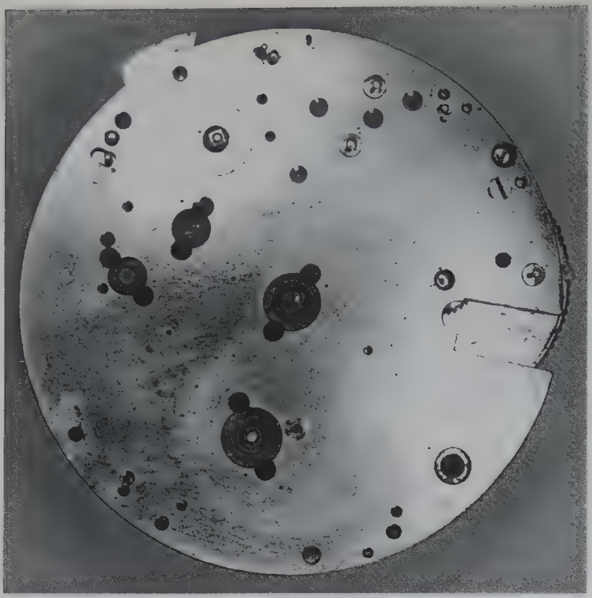


f

Plate 6

a. Cat. no. 6.
b. Cat. no. 6.
c. Cat. no. 6, gear trains.
d. Cat. no. 7.
e. Cat. no. 7.
f. Cat. no. 7.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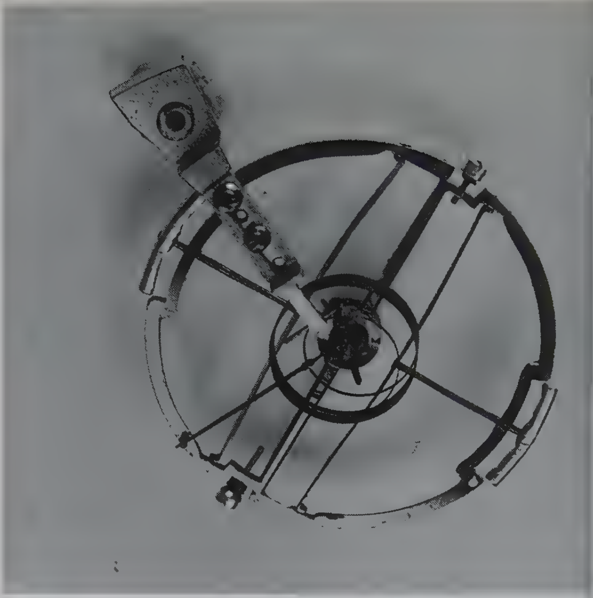
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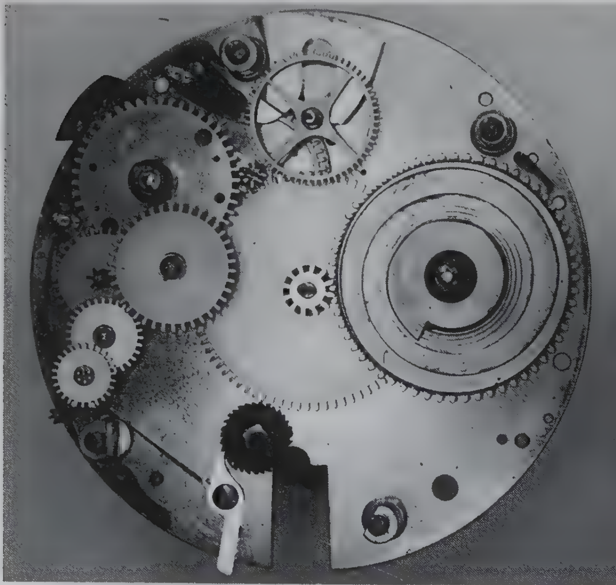
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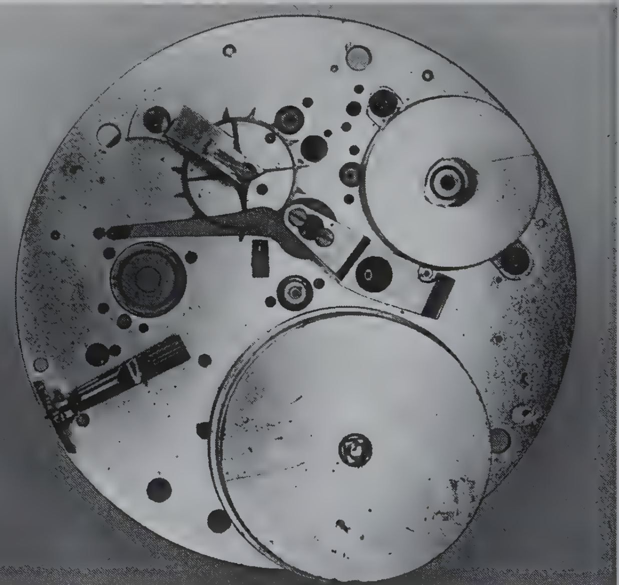
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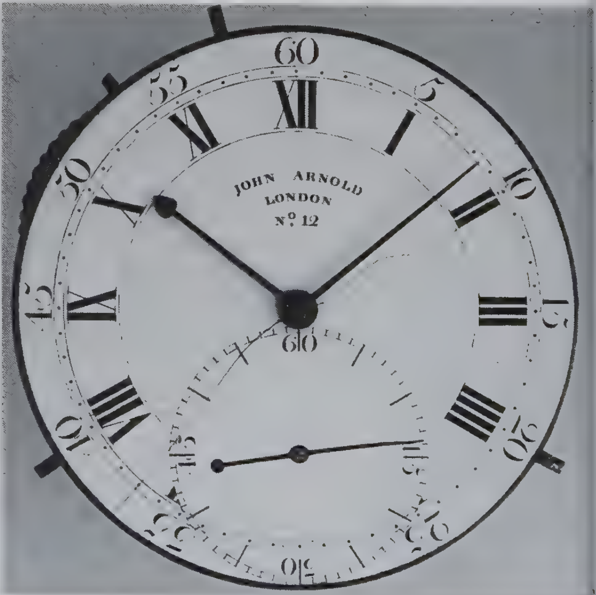
JOHN ARNOLD
LONDON
Nº 12
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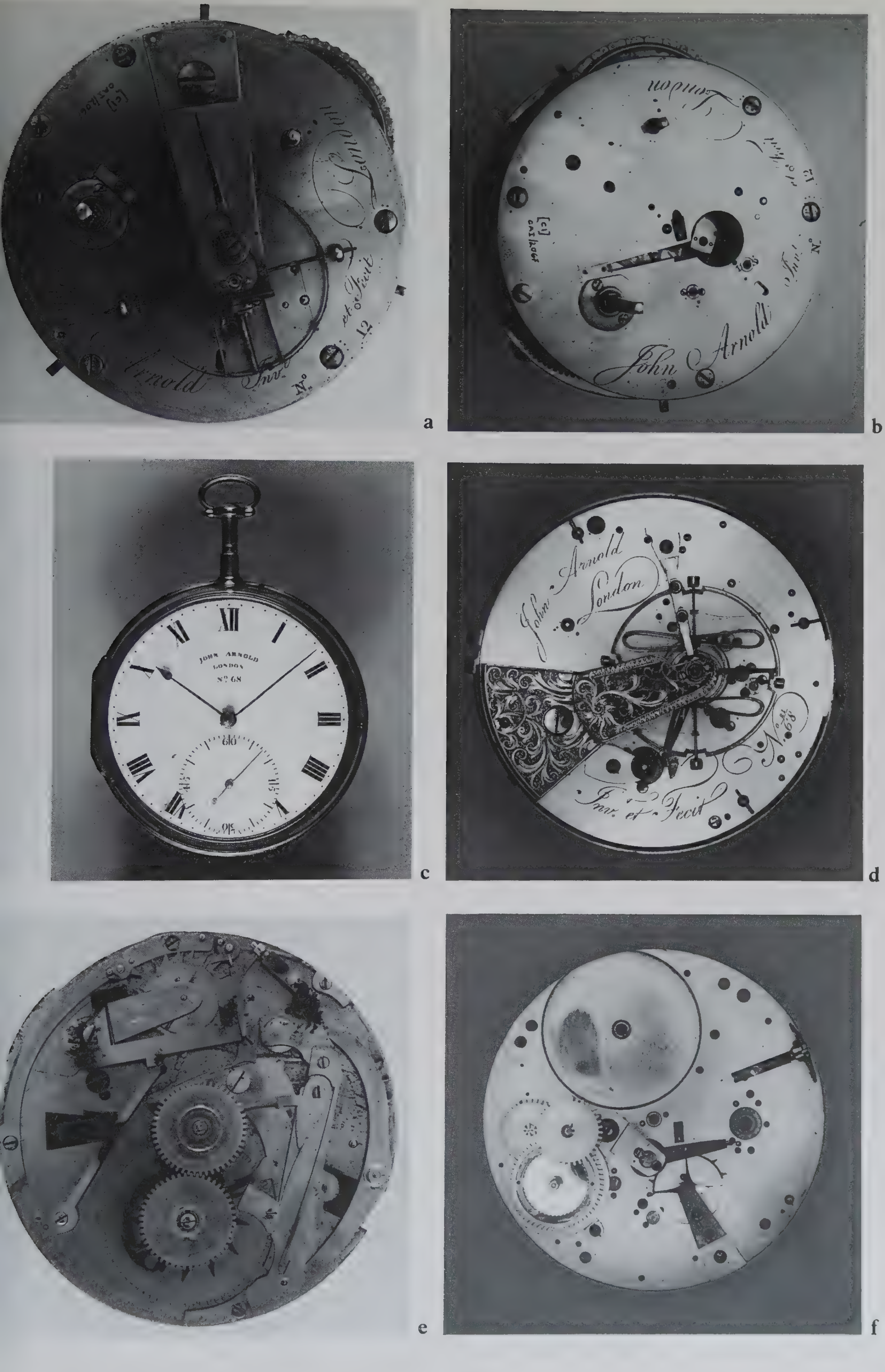
a
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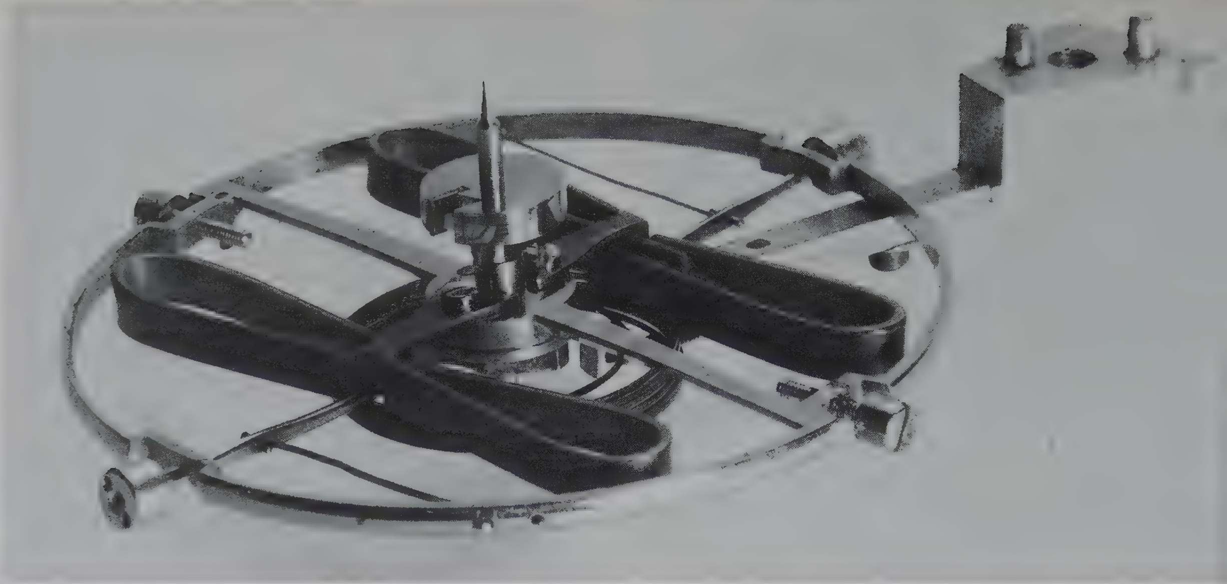
John Arnold
London
Inv. et Fecit
No 12
JOHN ARNOLD
LONDON
No 68

Plate 7

a. Cat. no. 7.
b. Cat. no. 7.
c. Cat. no. 8.
d. Cat. no. 8.
e. Cat. no. 8, repeating work.
f. Cat. no. 8, backplate removed.

Plate 8

a. Cat. no. 8.
b. Cat. no. 9.
c. Cat. no. 9, dust cover.
d. Cat. no. 9.
e. Cat. no. 9.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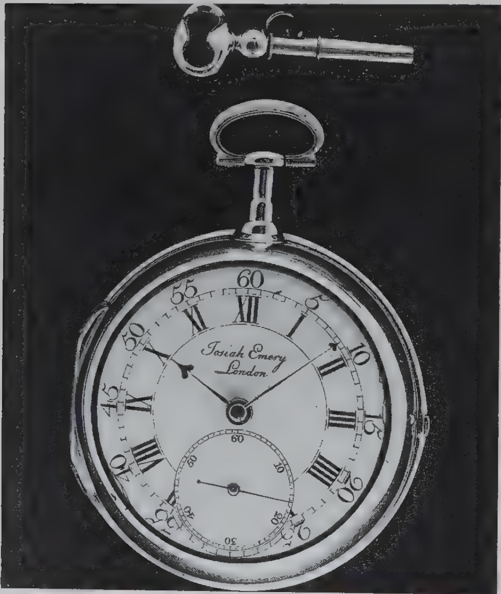
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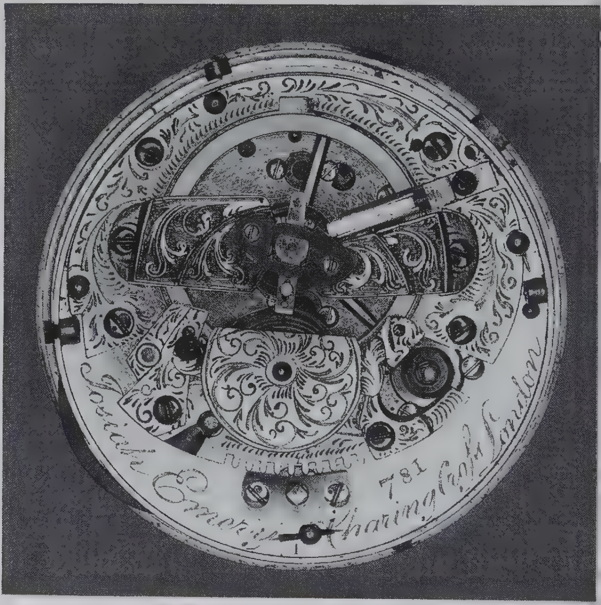
London
b


Josiah Emery Charing Cross London
781
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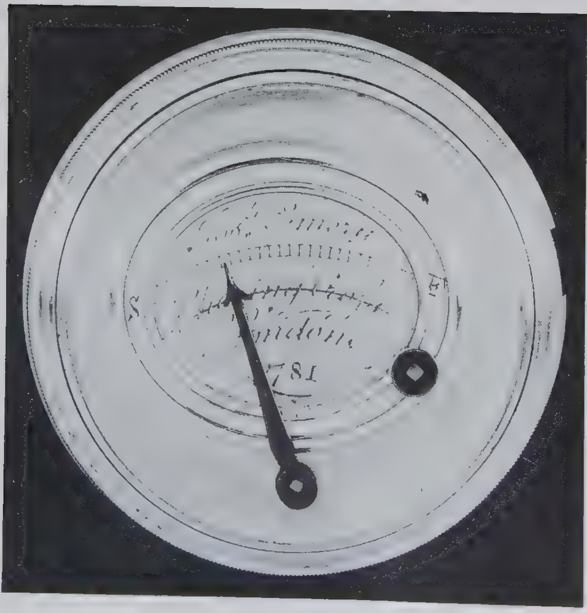
S
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London
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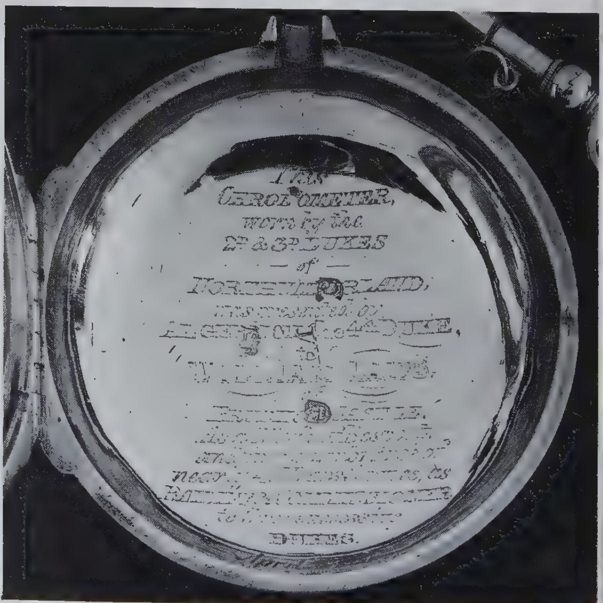
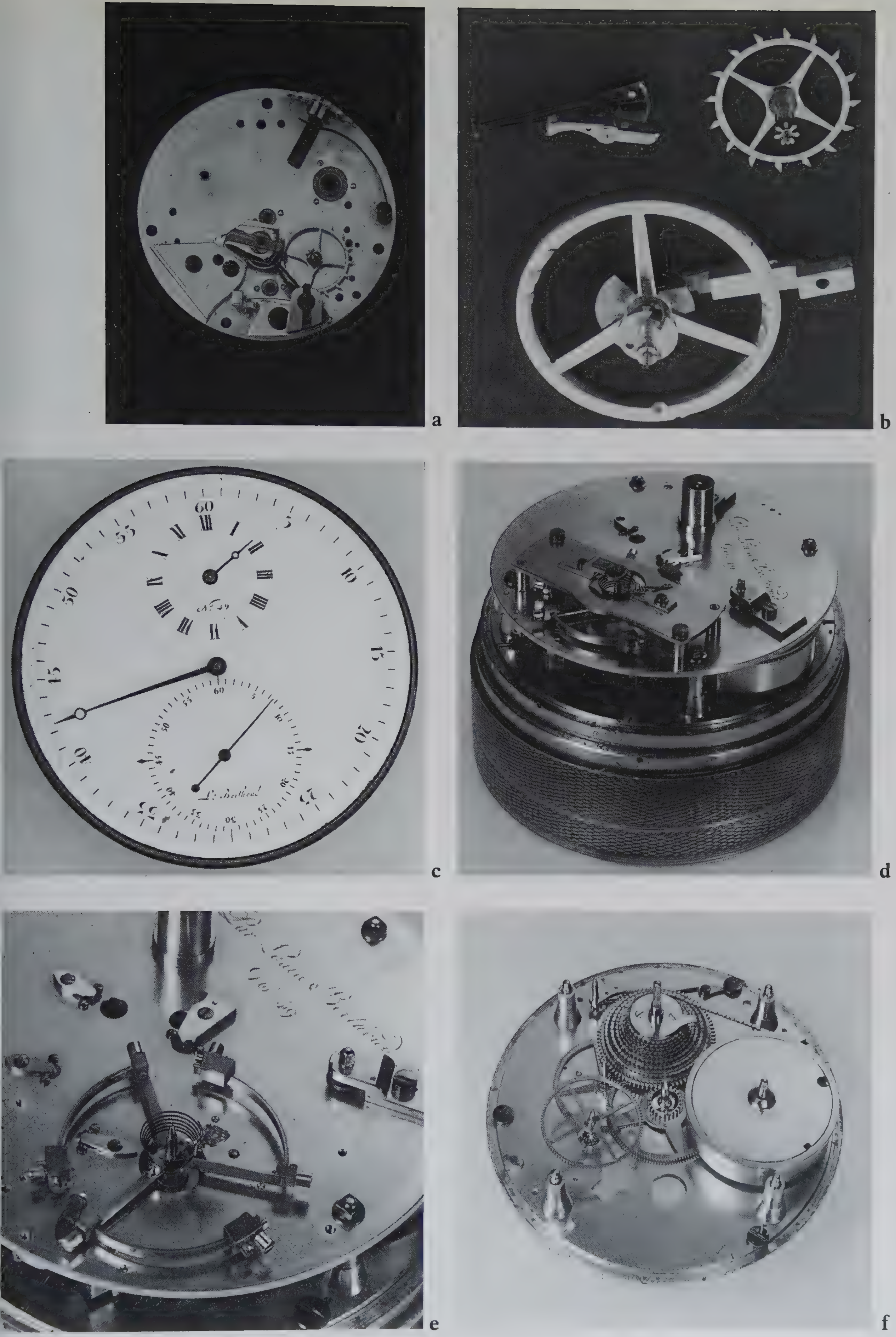

This
Chronometer,
worn by the
2d & 3d DUKES
of
NORTHUMBERLAND,
DUKES.
e


a
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No 49
Ls Berthoud
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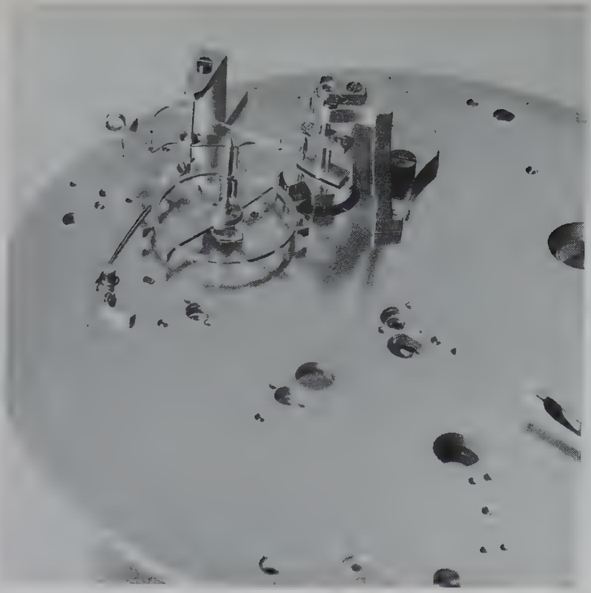
Plate 9

a. Cat. no. 9.
b. Cat. no. 9.
c. Cat. no. 10.
d. Cat. no. 10.
e. Cat. no. 10, balance bridge removed.
f. Cat. no. 10, backplate removed.

Plate 10

a. Cat. no. 10.
b. Cat. no. 10.
c. Cat. no. 11.
d. Cat. no. 11.
e. Cat. no. 11, dial on the right, 'Lucard' partly cut into by winding hole. Cat. no. 121 dial on the left.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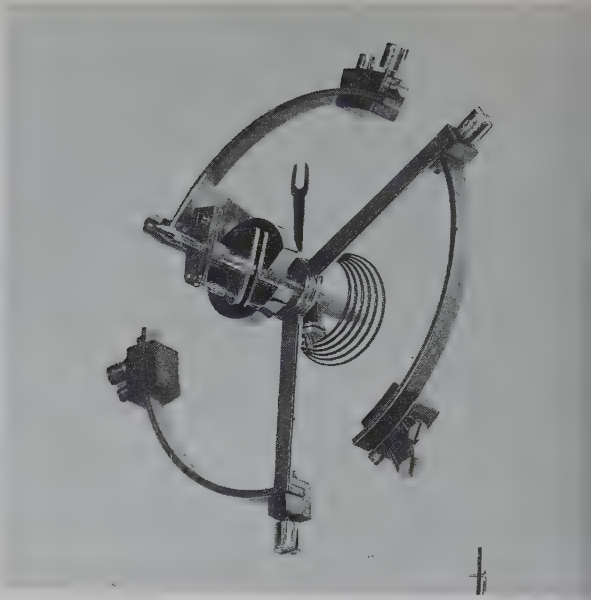
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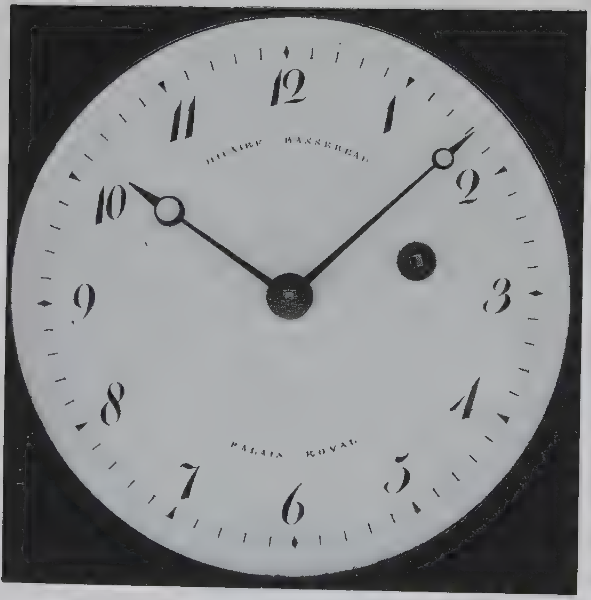
HILAIRE BASSEREAU
PALAIS ROYAL
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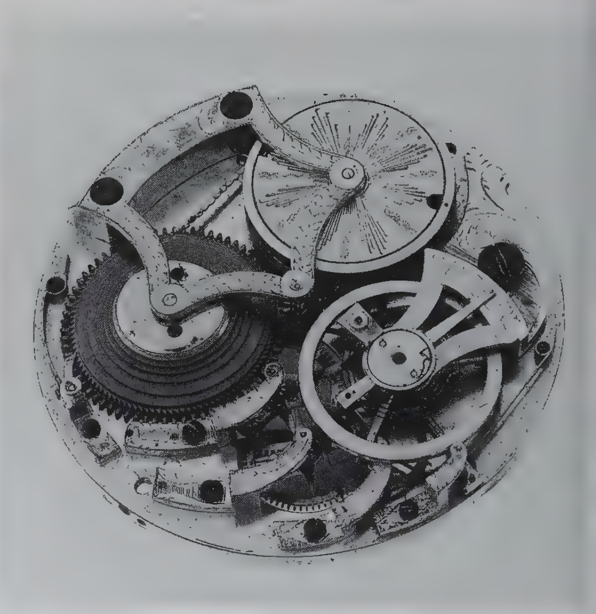
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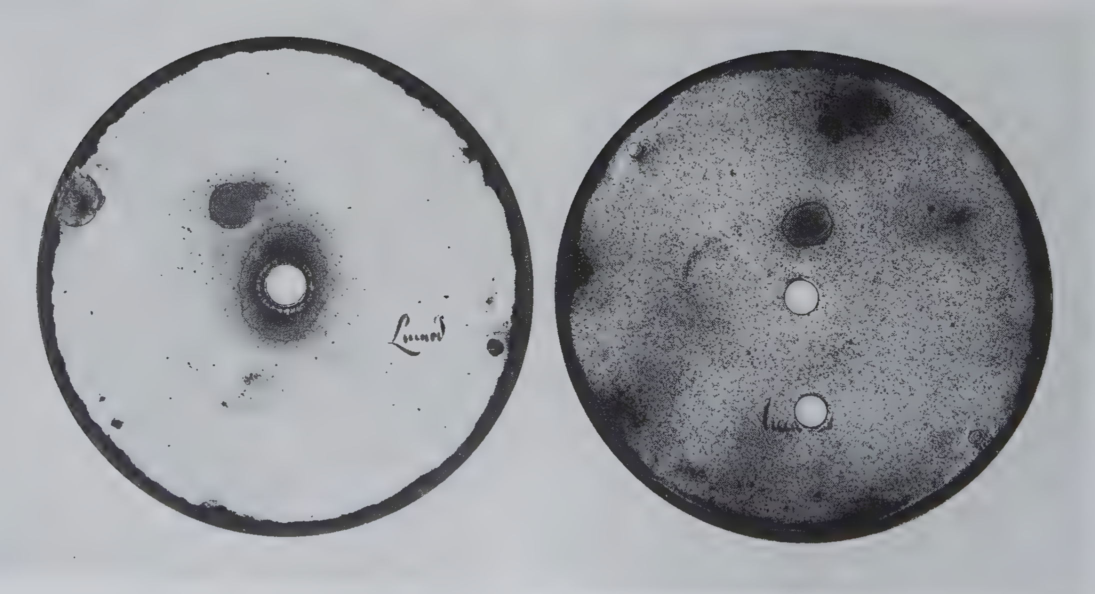

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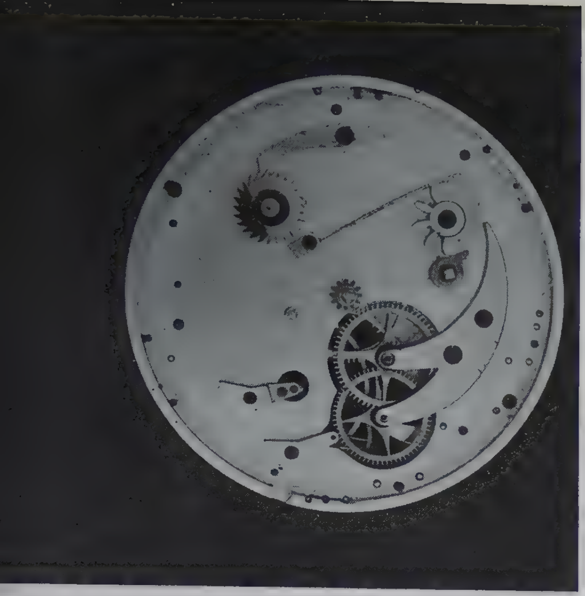
Plate 11

a. Cat. no. 11, under dial.
b. Cat. no. 11, the cuvette.
c. Cat. no. 12.
d. Cat. no. 12.
e. Cat. no. 13.
f. Cat. no. 13.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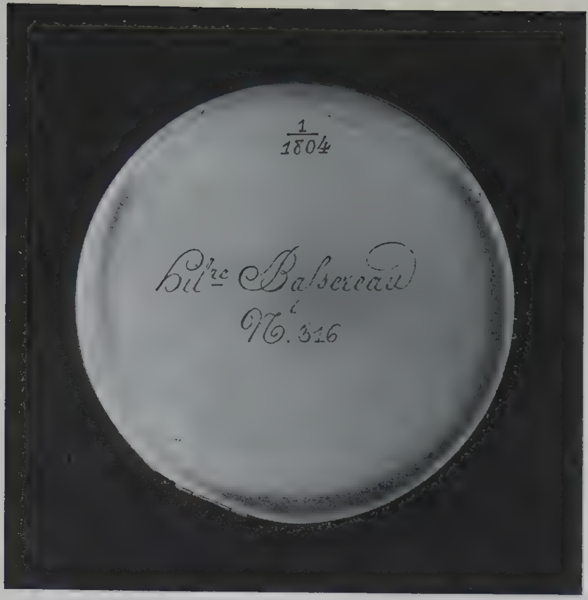
$\frac{1}{1804}$
Hil^re Balsereau
N^o. 316
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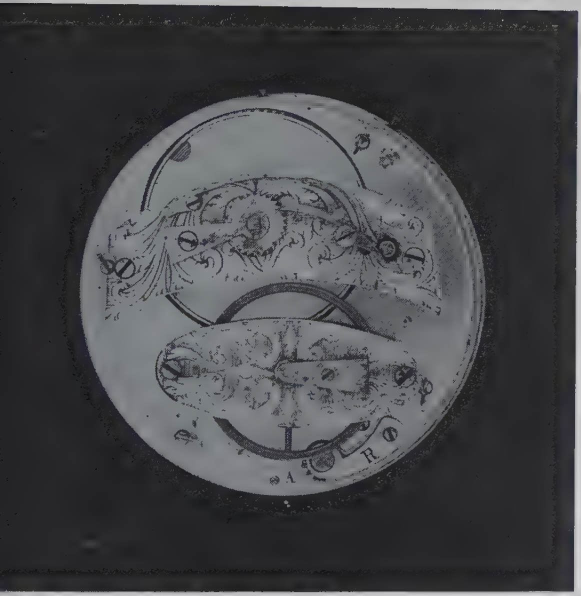

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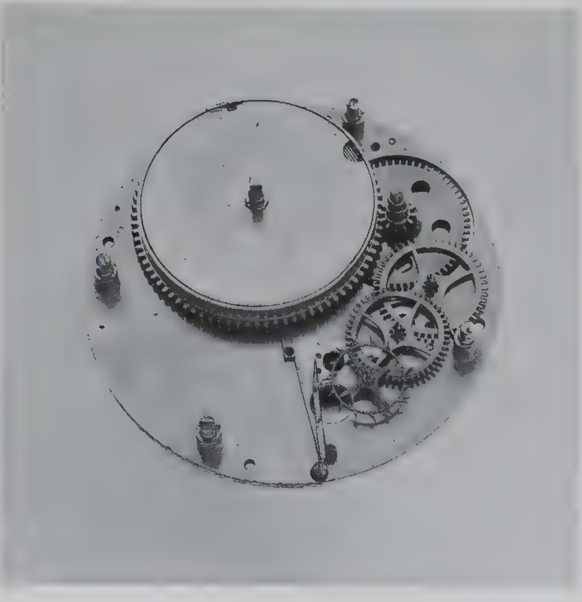
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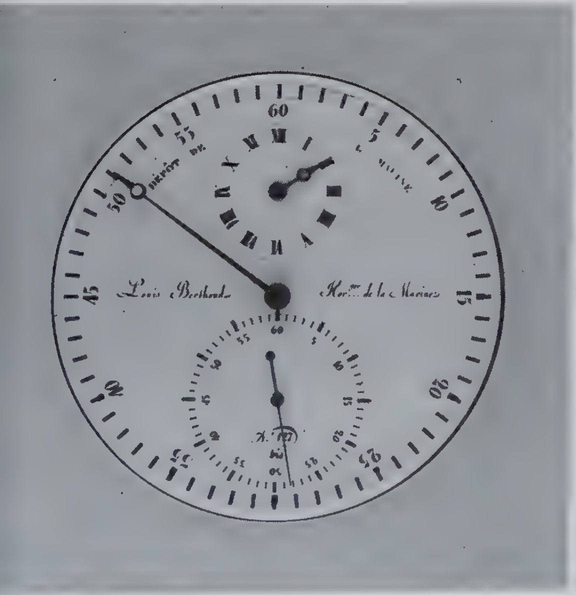
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DEPOT DE
MARINE
Louis Berthoud
Hor^ier de la Marine
e

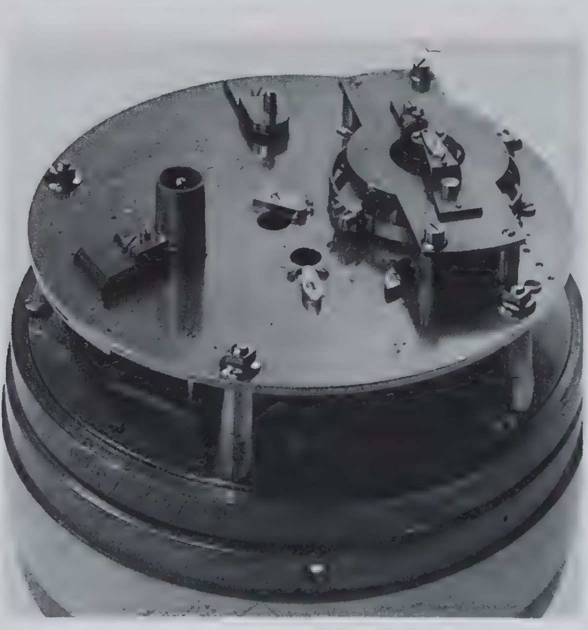
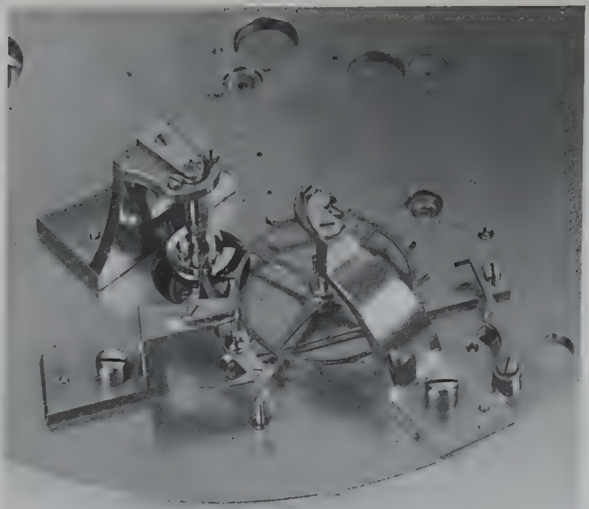

f

Plate 12

a. Cat. no. 13.
b. Cat. no. 13.
c. Cat. no. 14.
d. Cat. no. 14.
e. Cat. no. 15.
f. Cat. no. 15.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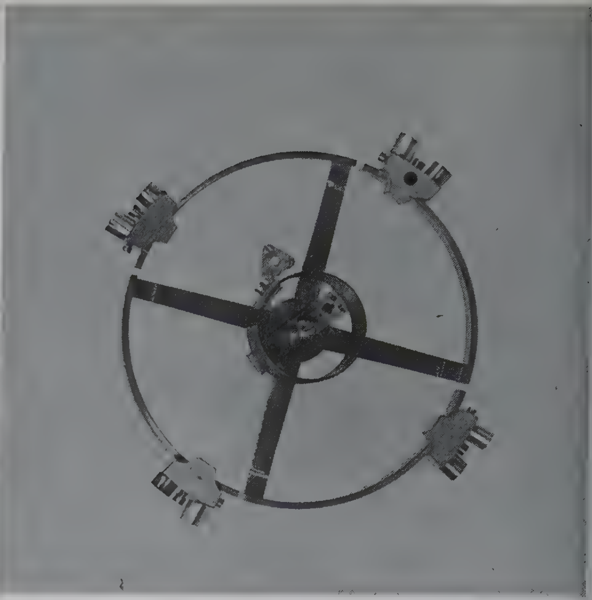
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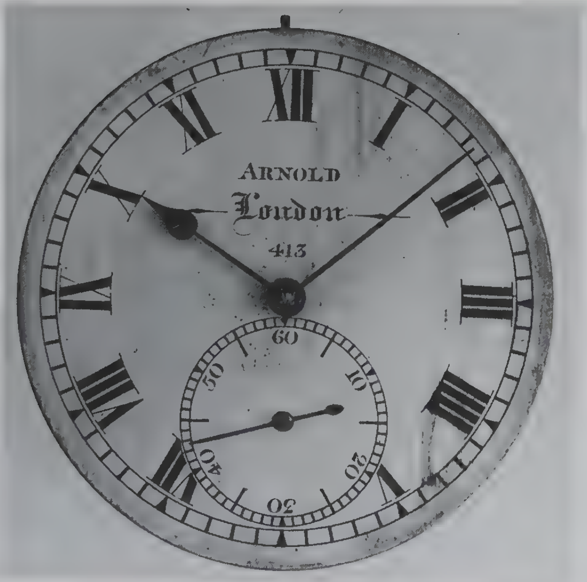
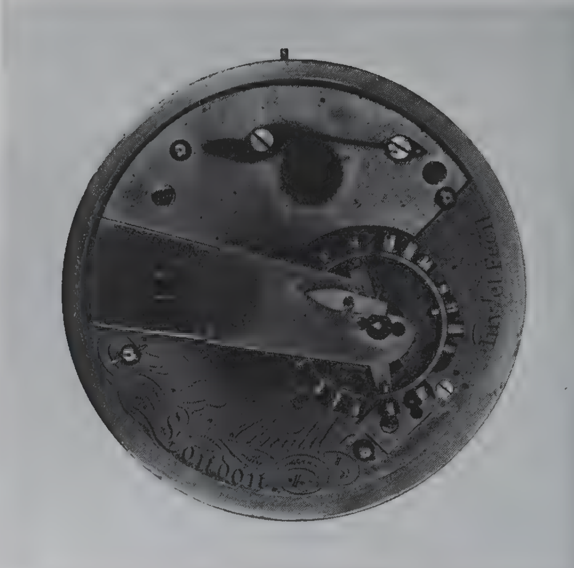

ARNOLD
London
413
c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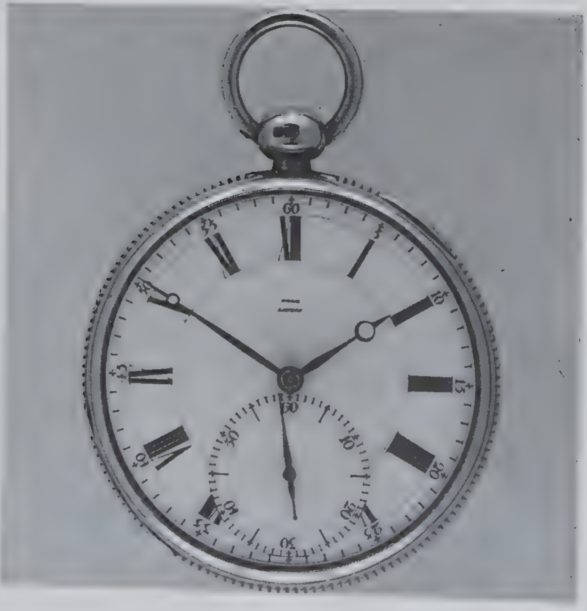

e

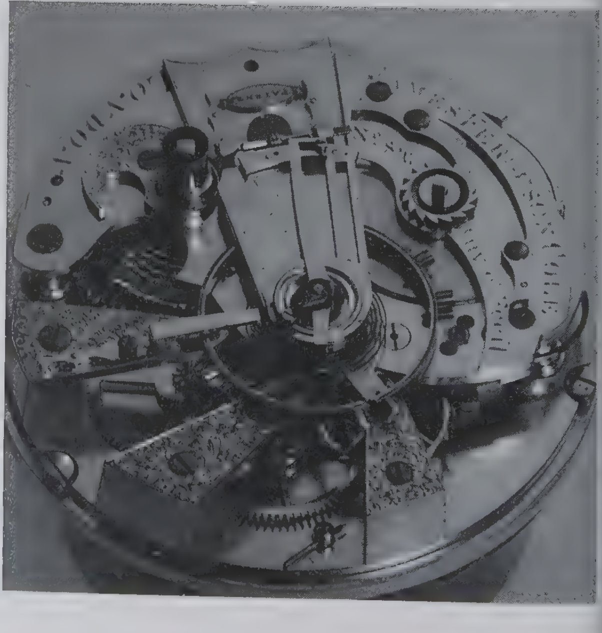
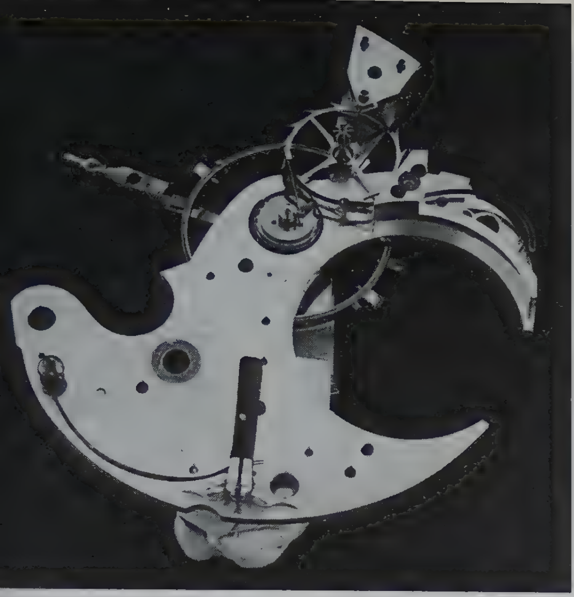
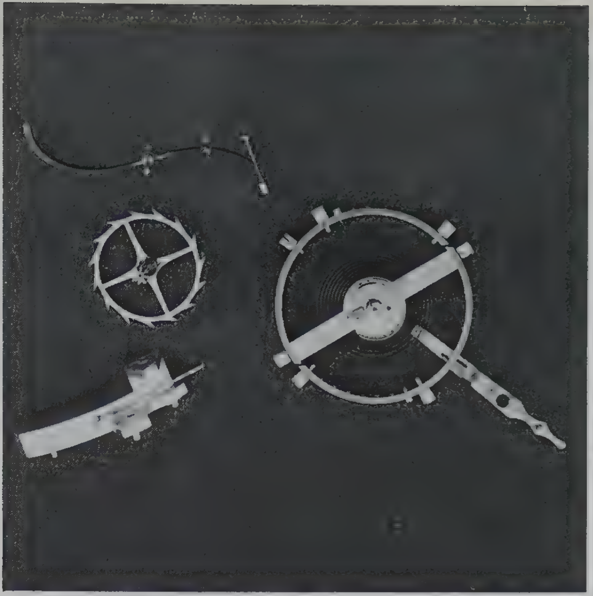

f

Plate 13

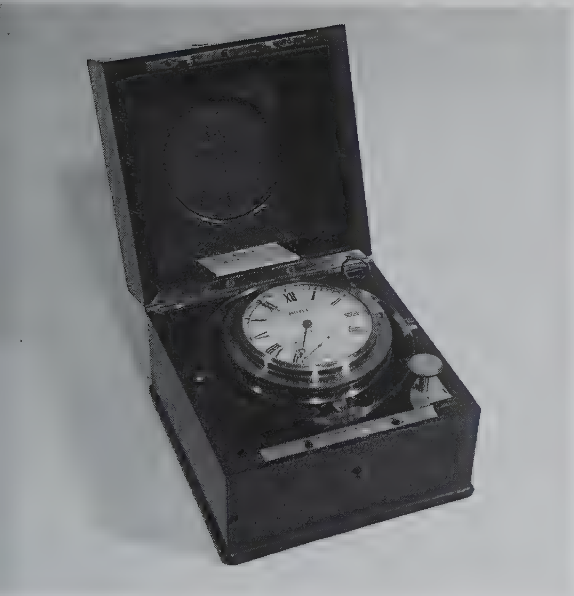
a. Cat. no. 15.
b. Cat. no. 15.
c. Cat. no. 16.
d. Cat. no. 16.
e. Cat. no. 16.
f. Cat. no. 16.



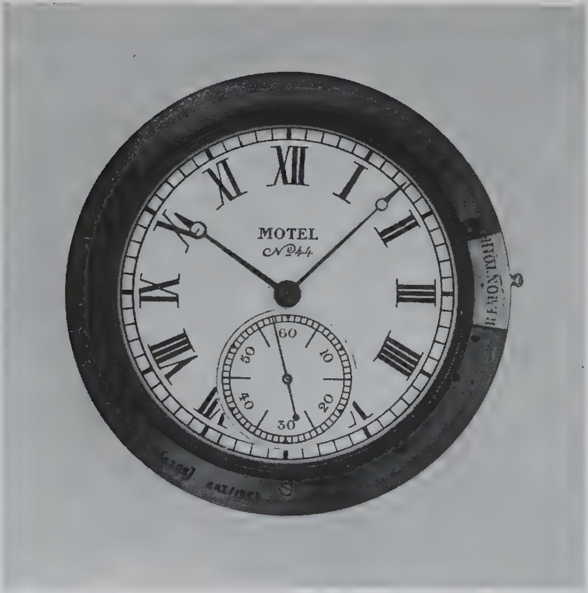
a



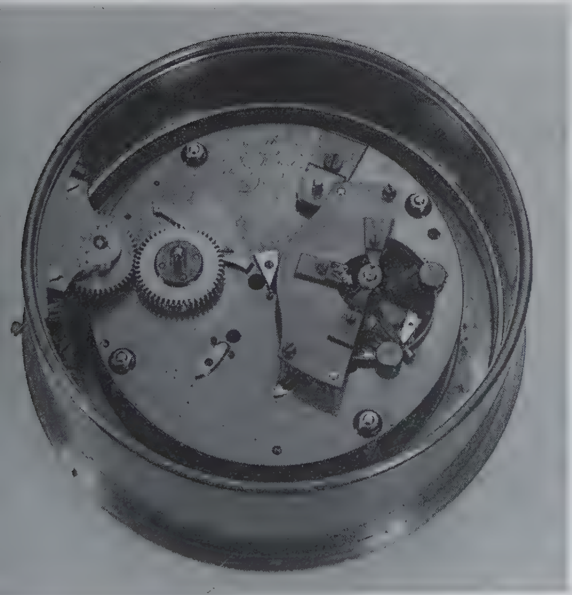
b



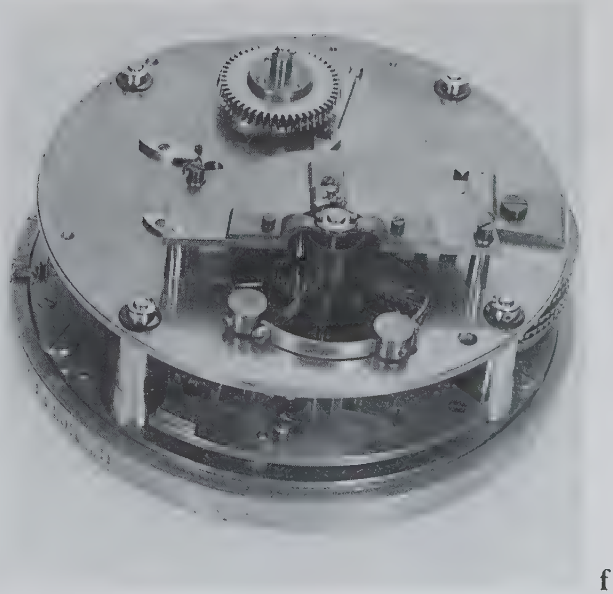
c



d



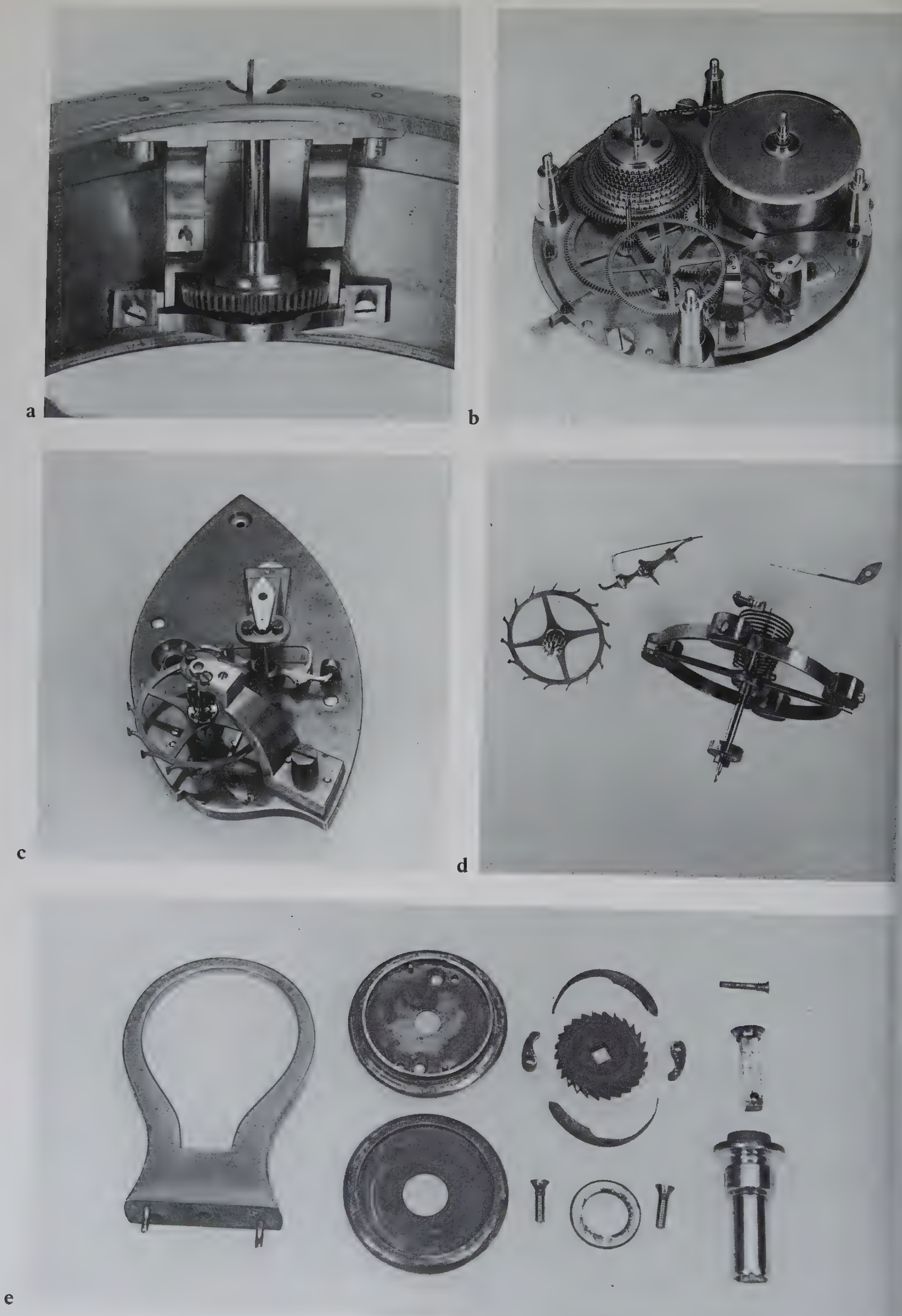
e



f

Plate 14

a. Cat. no. 16, winding wheel.
b. Cat. no. 16.
c. Cat. no. 16.
d. Cat. no. 16.
e. Cat. no. 16, winding key dismantled.



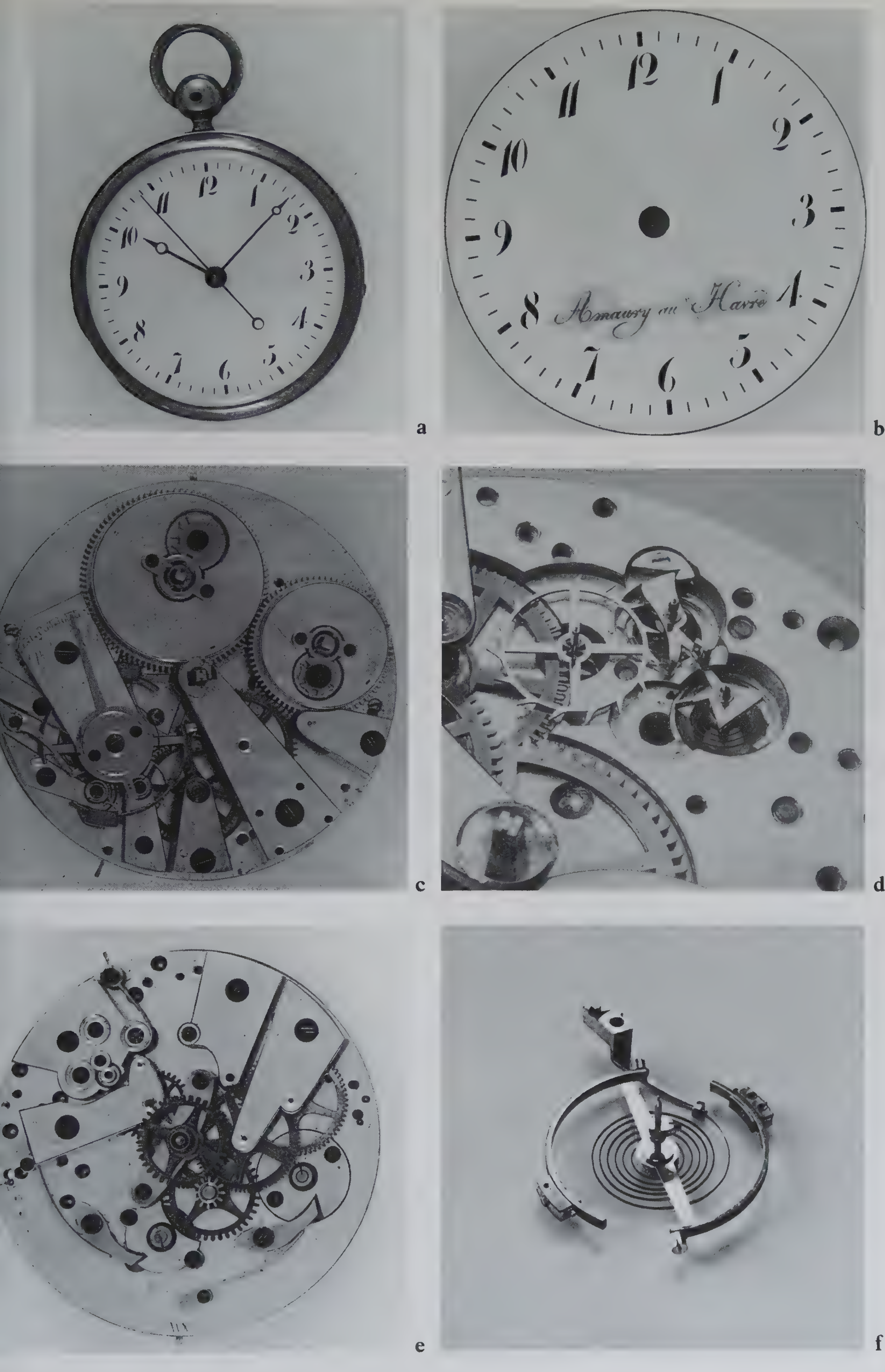
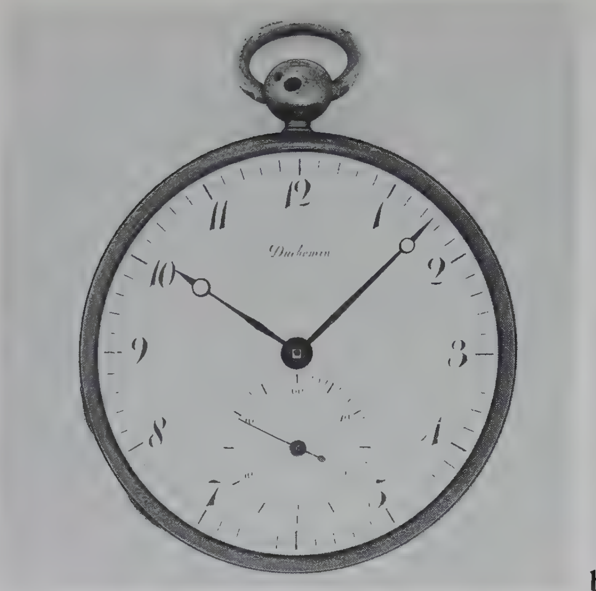

Amaury au Havre
a
b
c
d
e
f

Plate 15

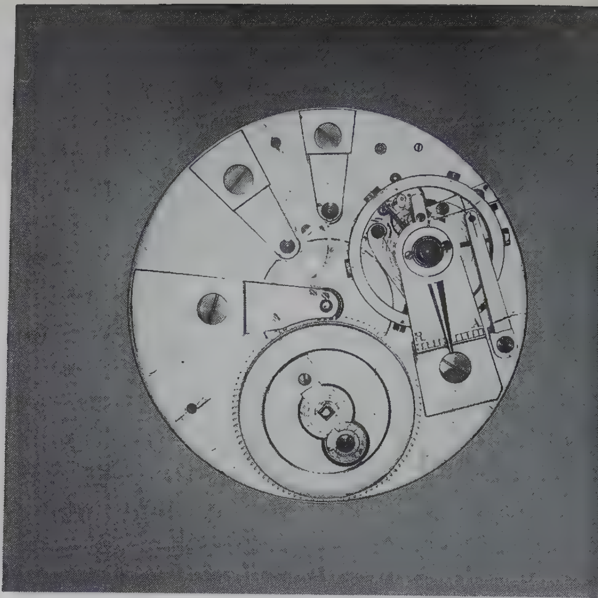
a. Cat. no. 17.
b. Cat. no. 17, dial waxed to show signature.
c. Cat. no. 17.
d. Cat. no. 17.
e. Cat. no. 17, under dial.
f. Cat. no. 17.

Plate 16

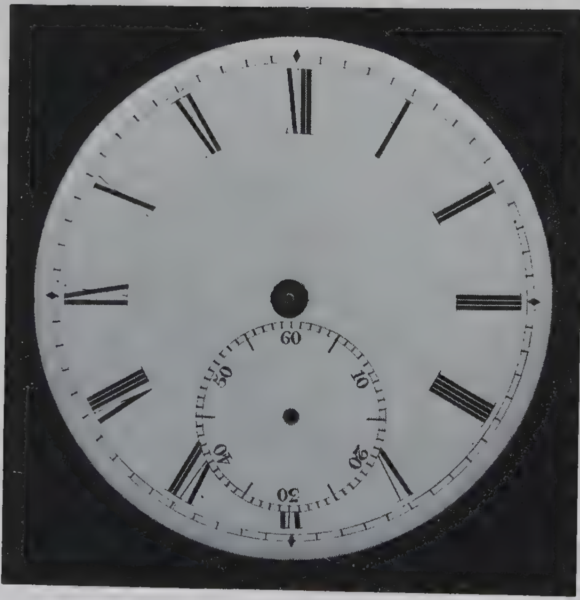
- **a.** Cat. no. 18.
- **b.** Cat. no. 18.
- **c.** Cat. no. 19.
- **d.** Cat. no. 19.
- **e.** Cat. no. 19.
- **f.** Cat. no. 19.



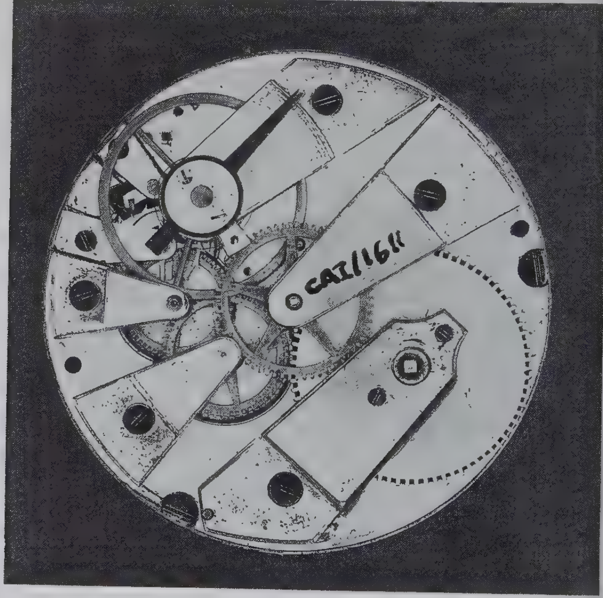
a



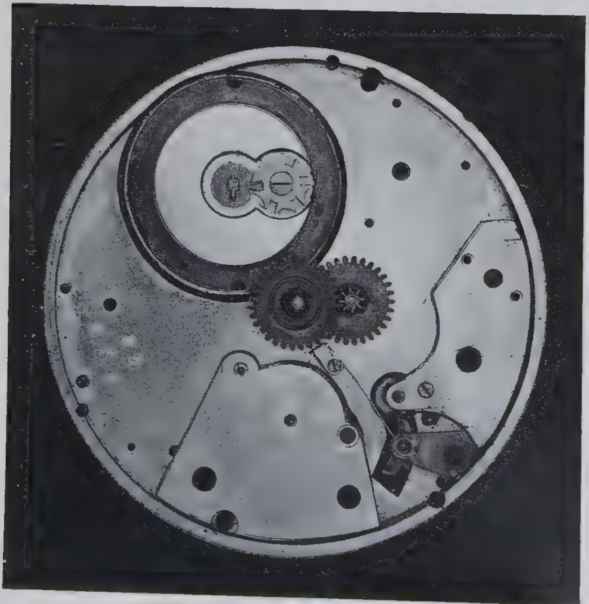
b


60
10
20
30
40
50

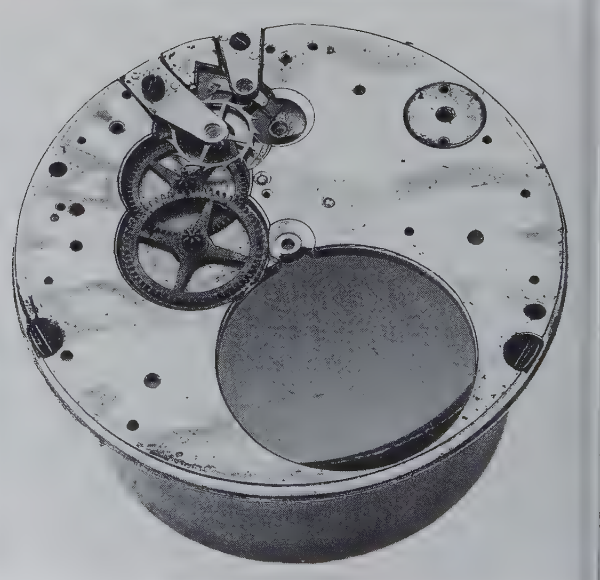
c



d



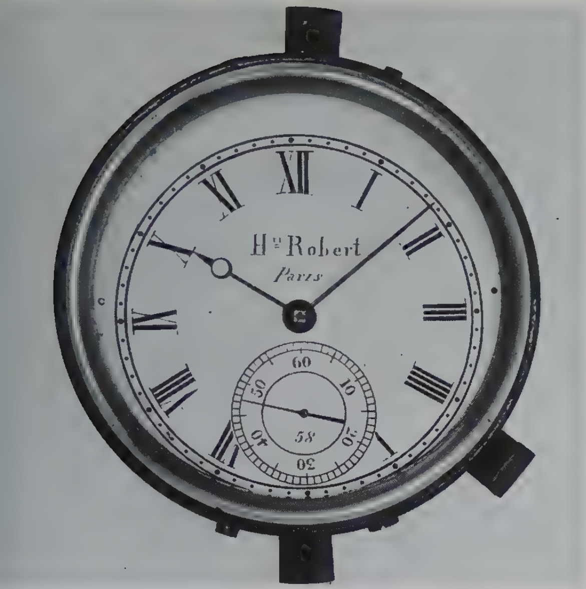
e



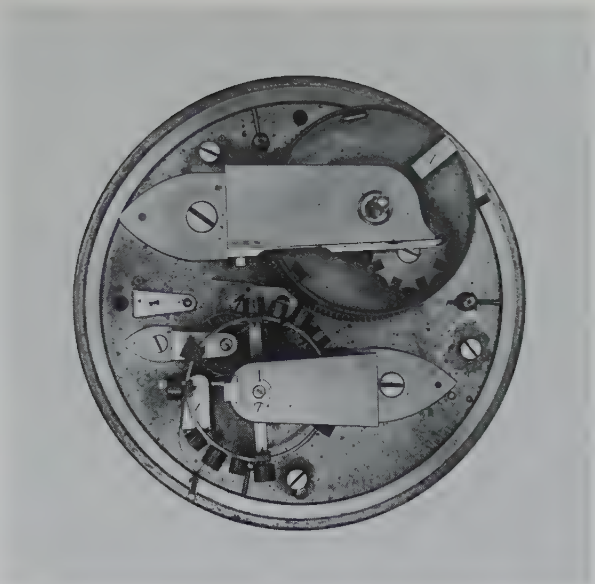
f

Plate 17

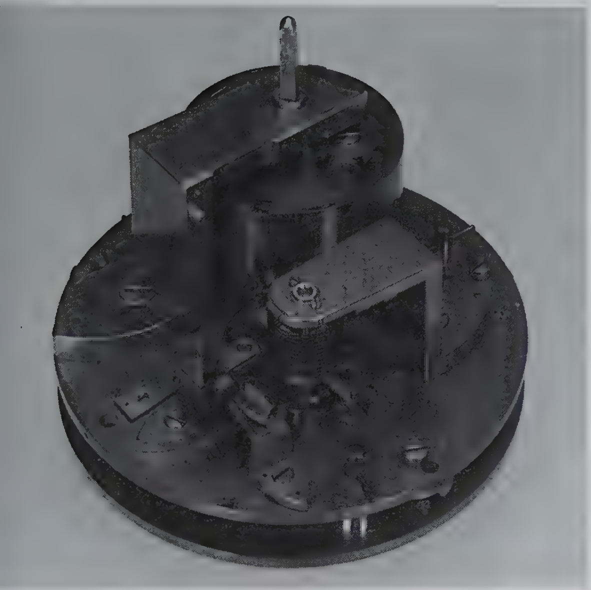
a. Cat. no. 20.
b. Cat. no. 20.
c. Cat. no. 20.
d. Cat. no. 20. Note the three retaining discs and the long train stop-arm.
e. Cat. no. 21.
f. Cat. no. 21.


Hri Robert
Paris

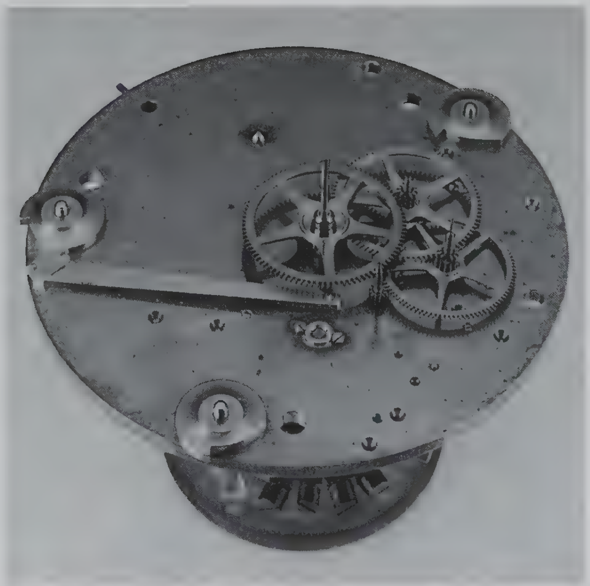
a



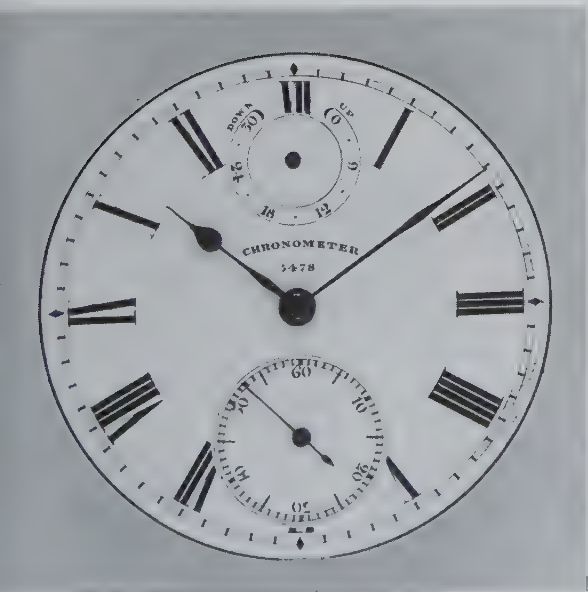
b



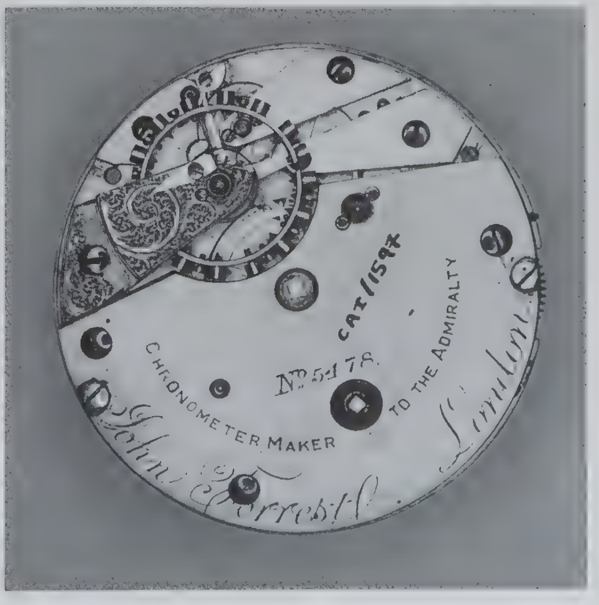
c



d


DOWN
UP
CHRONOMETER
5478

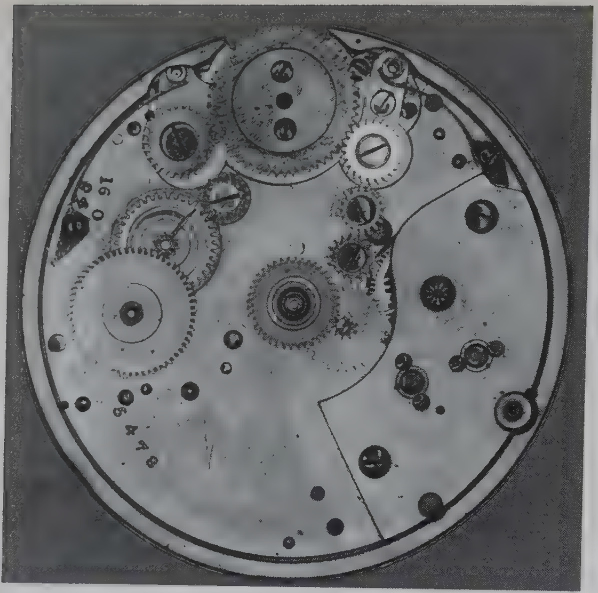
e


CAT/1594
No 5478
CHRONOMETER MAKER TO THE ADMIRALTY
John Forrest London

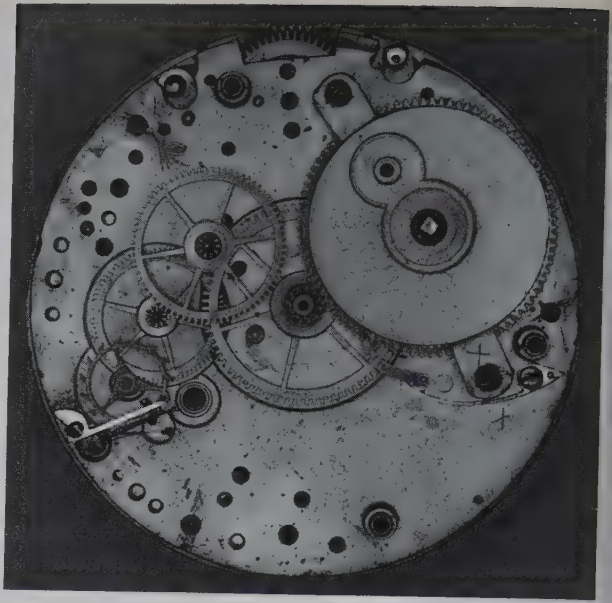
f

Plate 18

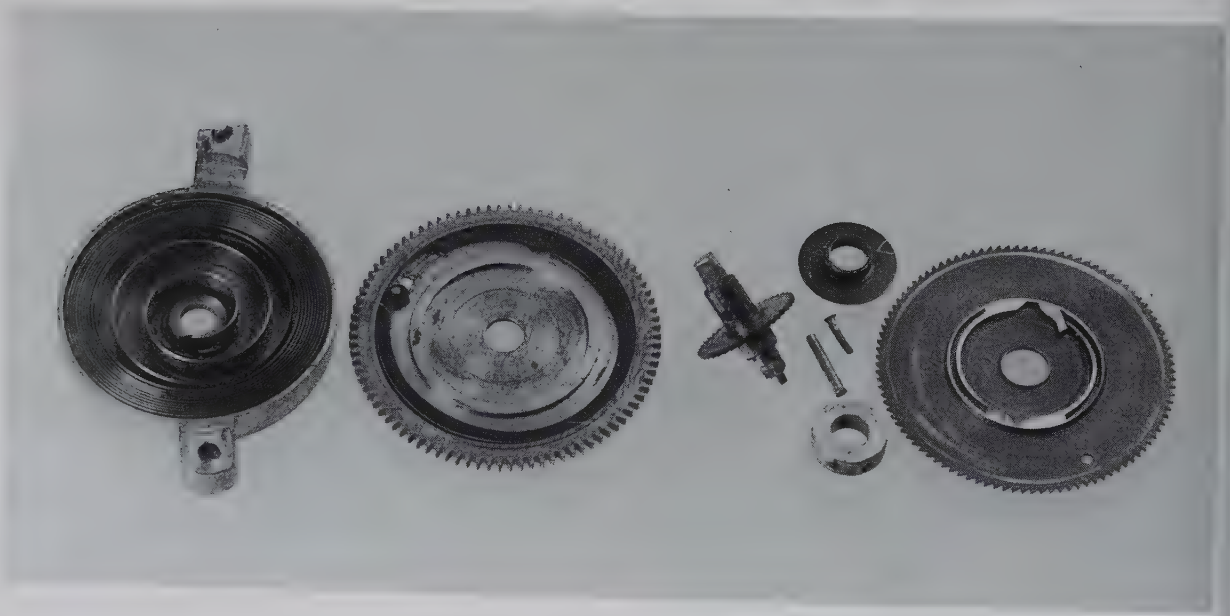
a. Cat. no. 21.
b. Cat. no. 21.
c. Cat. no. 21.
The barrel with its arbor, which has maintaining power.
d. Cat. no. 22.
e. Cat. no. 22.



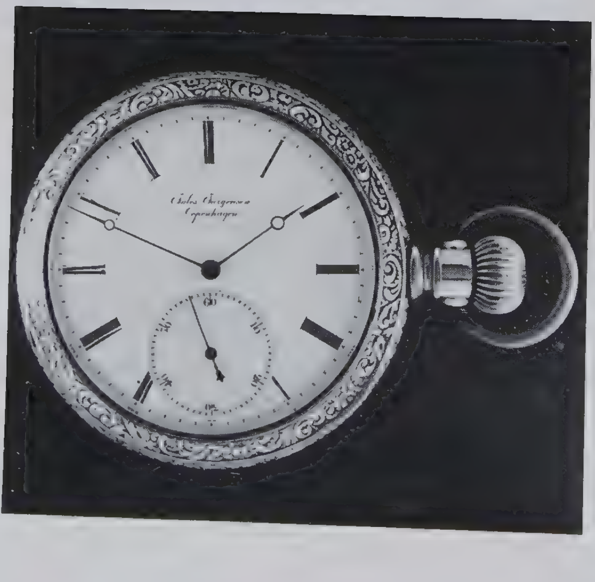
a



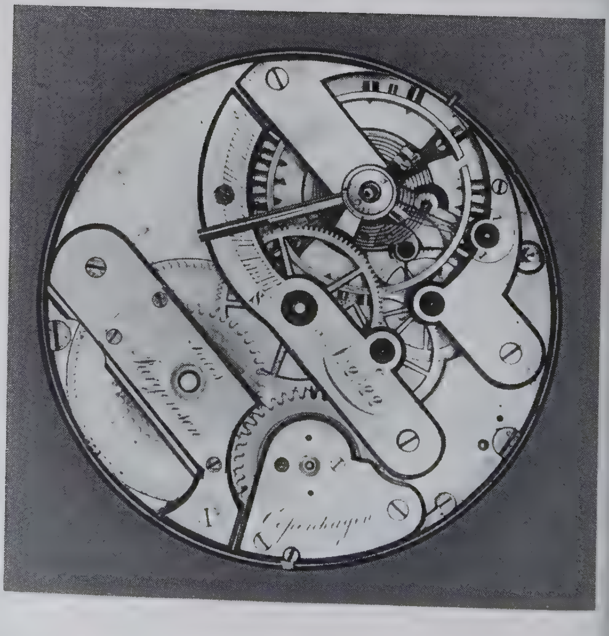
b



c


Copenhagen

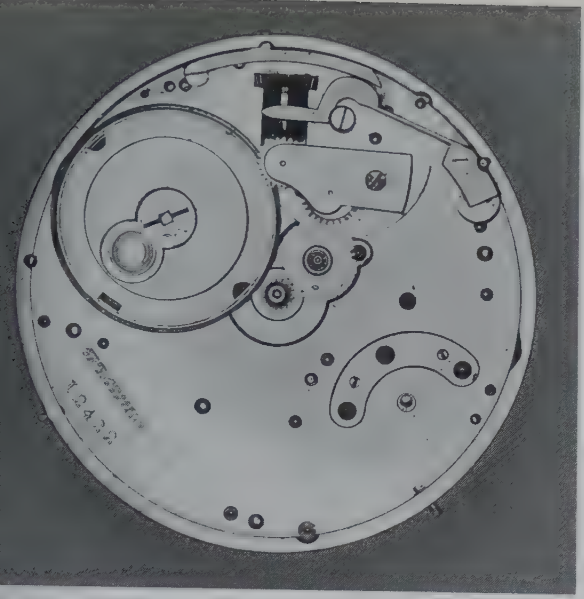
d

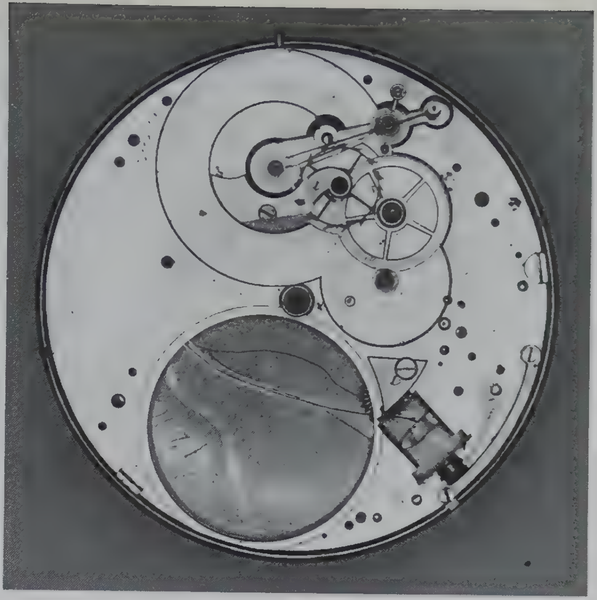

Copenhagen

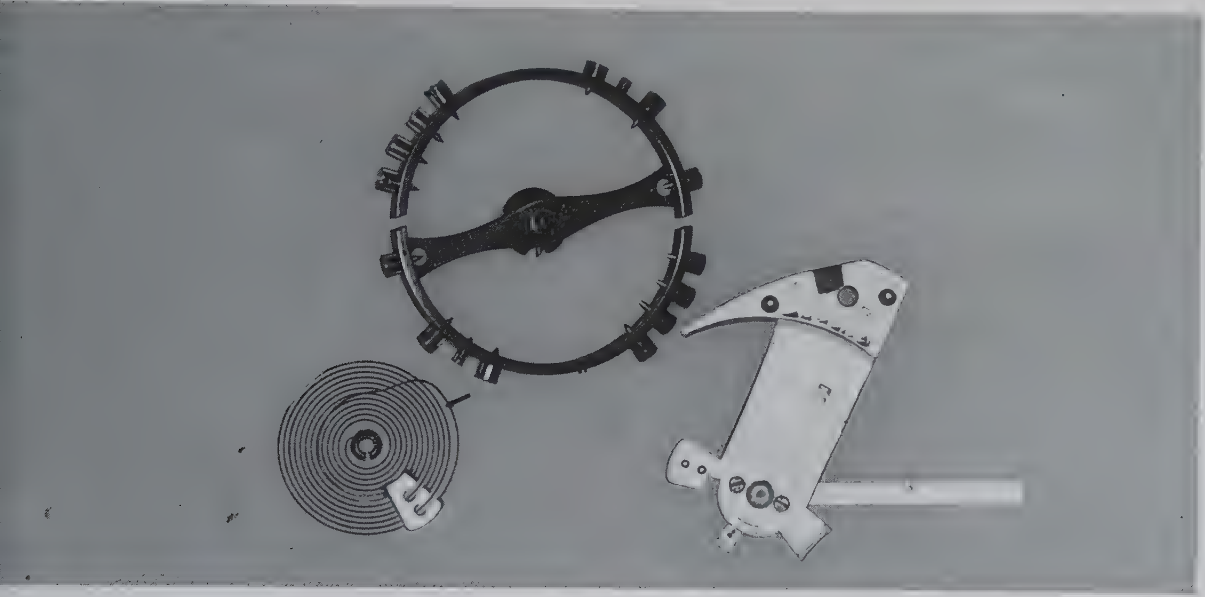
e

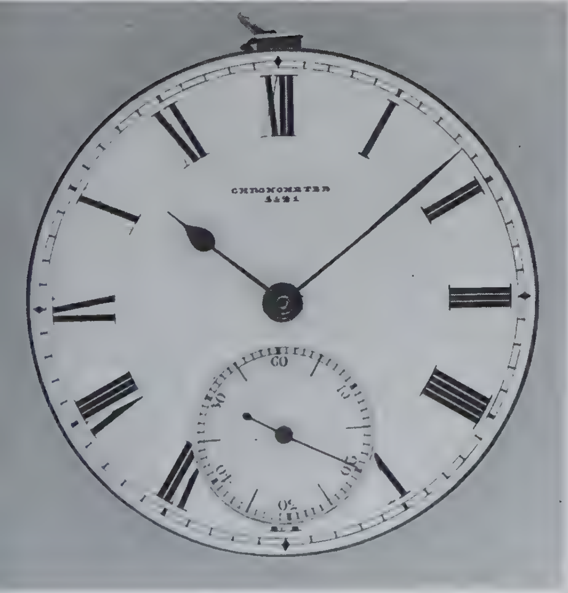
Plate 19

a. Cat. no. 22.
b. Cat. no. 22.
c. Cat. no. 22.
d. Cat. no. 23.
e. Cat. no. 23.


a


b


c


CHRONOMETER
5491
60
d

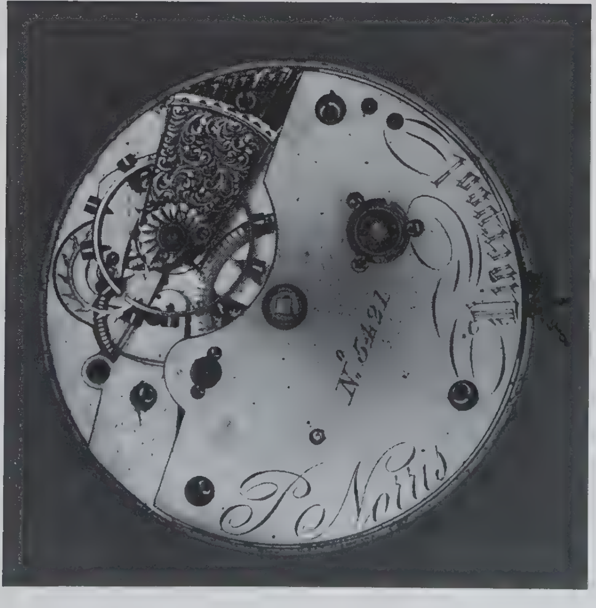
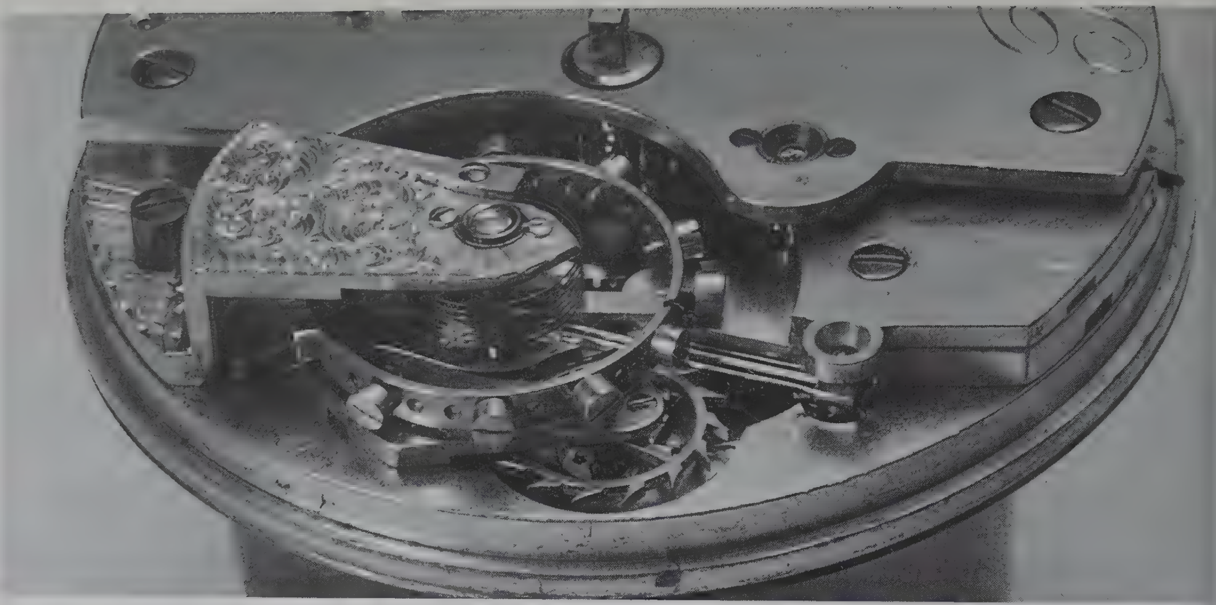
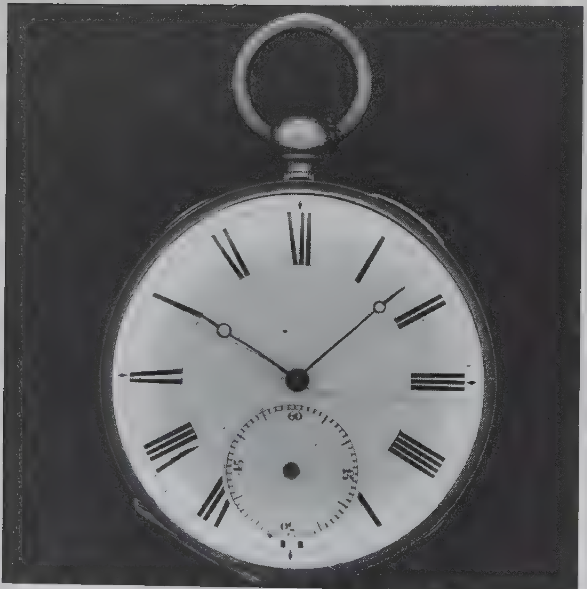

N.o 5491
P. Norris
e

Plate 20

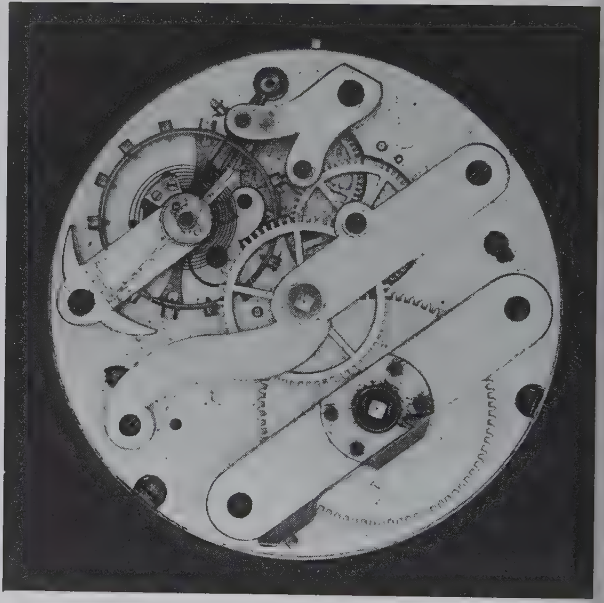
a. Cat. no. 23.
b. Cat. no. 24.
c. Cat. no. 24.
d. Cat. no. 25.
e. Cat. no. 25.



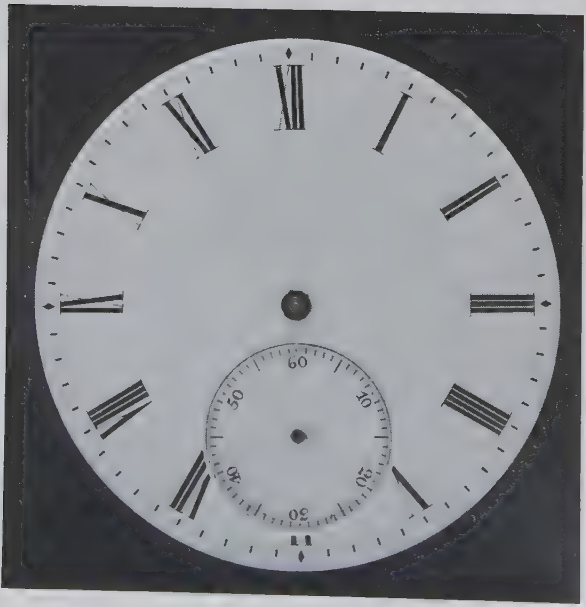
a



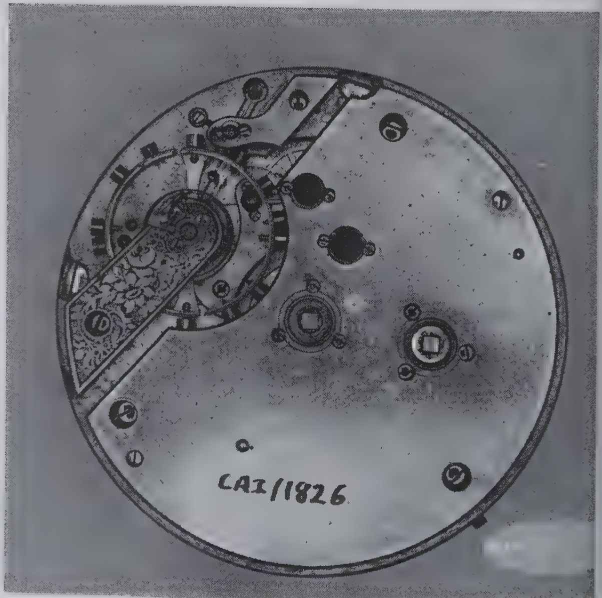
b



c



d



e

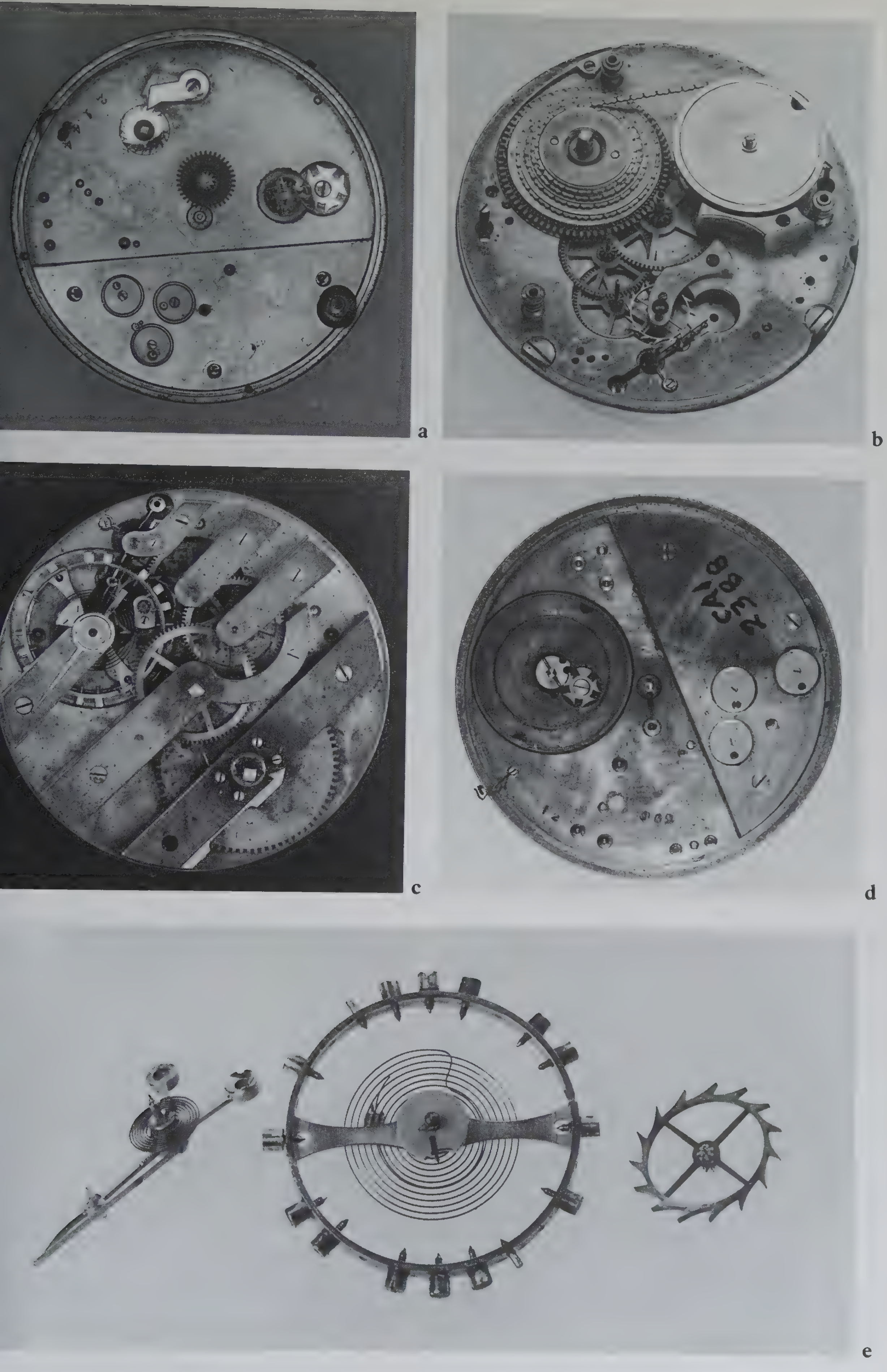
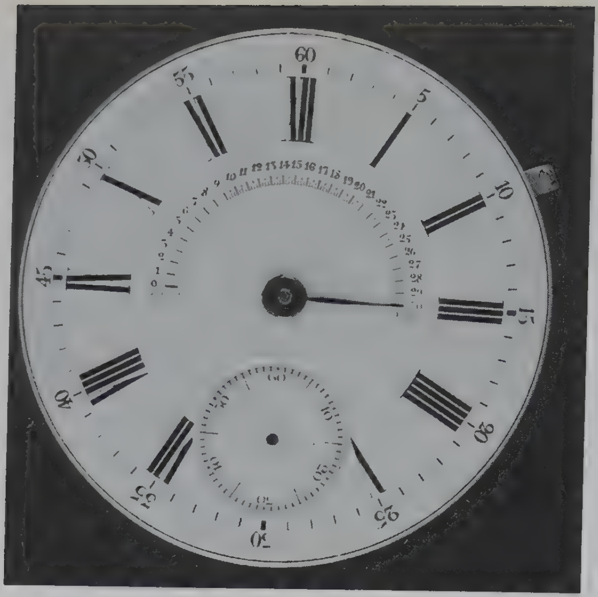


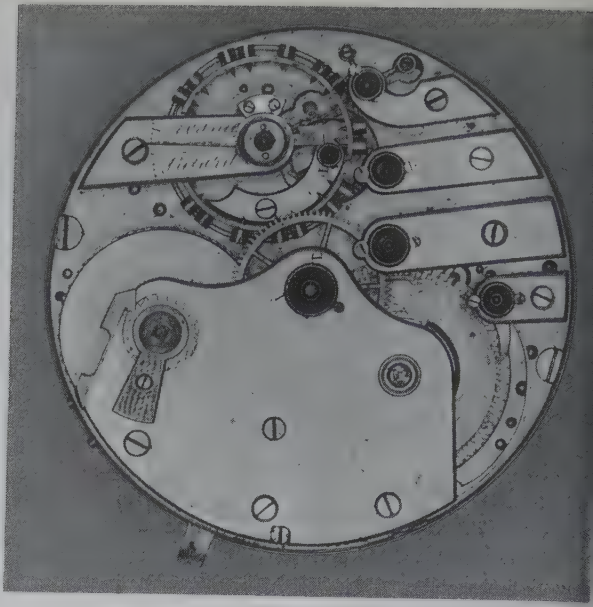
Plate 21

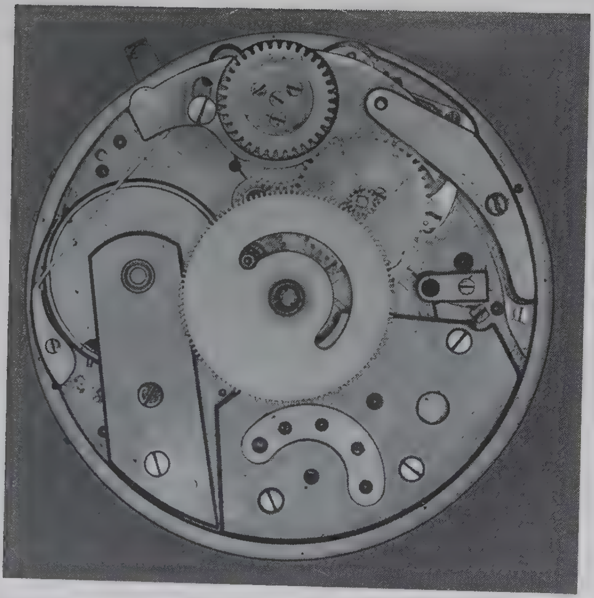
a. Cat. no. 25.
b. Cat. no. 25, backplate removed.
c. Cat. no. 26.
d. Cat. no. 26.
e. Cat. no. 26.

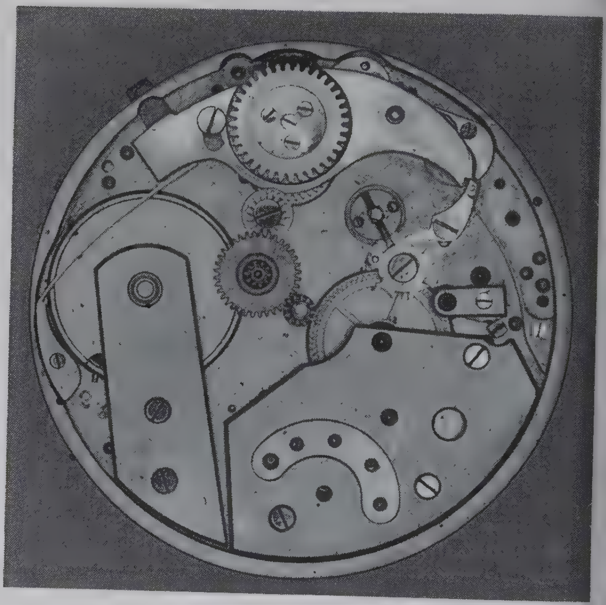
Plate 22

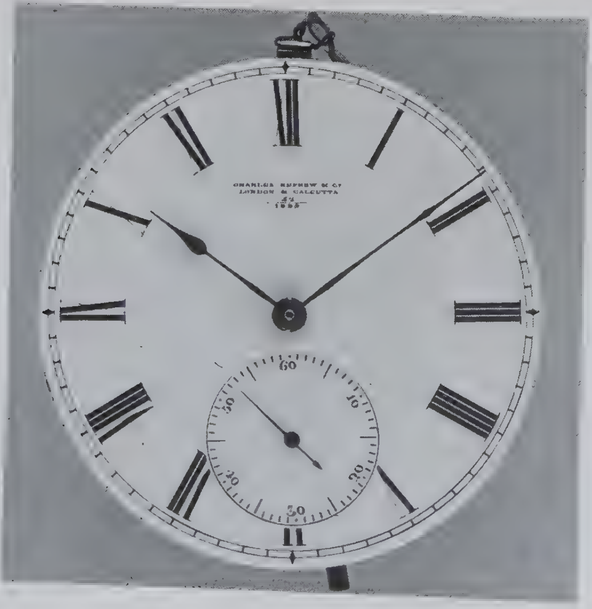
a. Cat. no. 27.
b. Cat. no. 27.
c. Cat. no. 27. The wheel with the semicircular cutout is the up-and-down wheel.
d. Cat. no. 27.
e. Cat. no. 28.
f. Cat. no. 28.


a


b


c


d


CHARLES NEPHEW & Co
LONDON & CALCUTTA
e

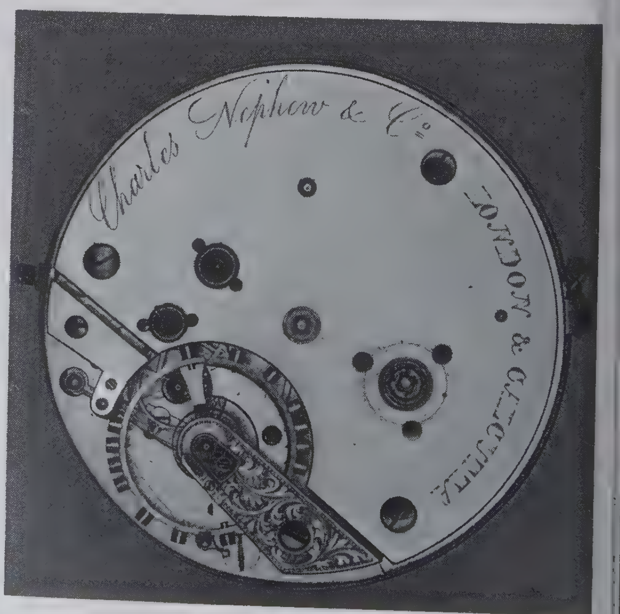
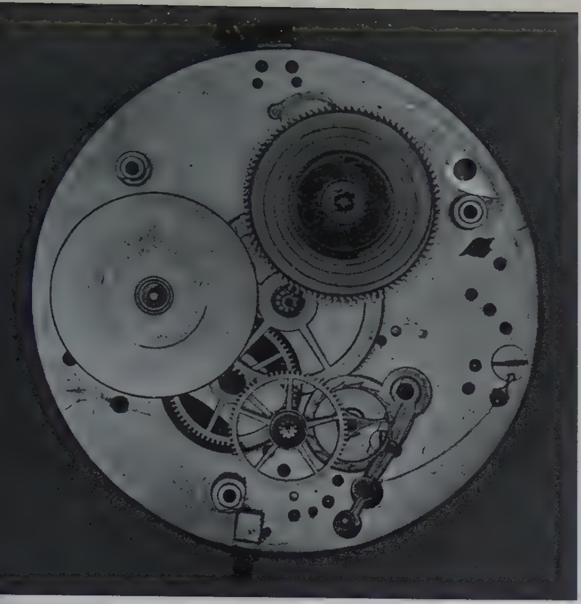
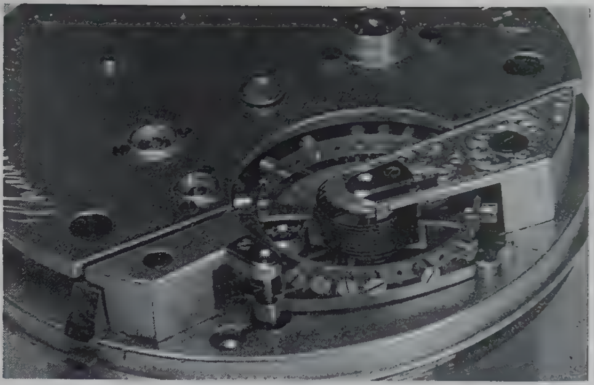
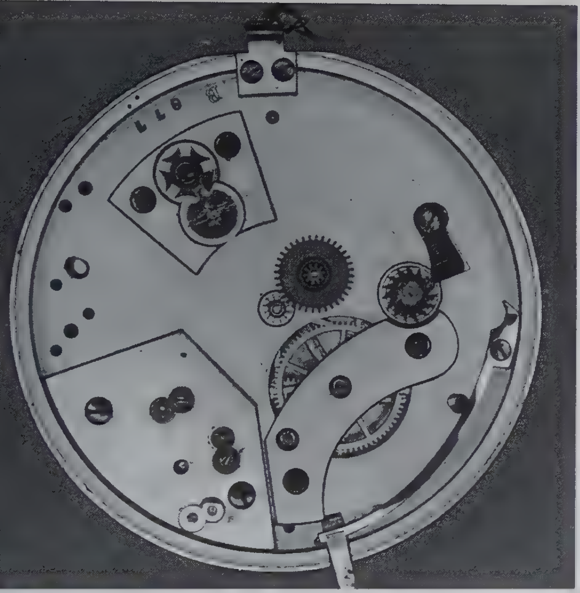

Charles Nephew & Co
LONDON & CALCUTTA
f

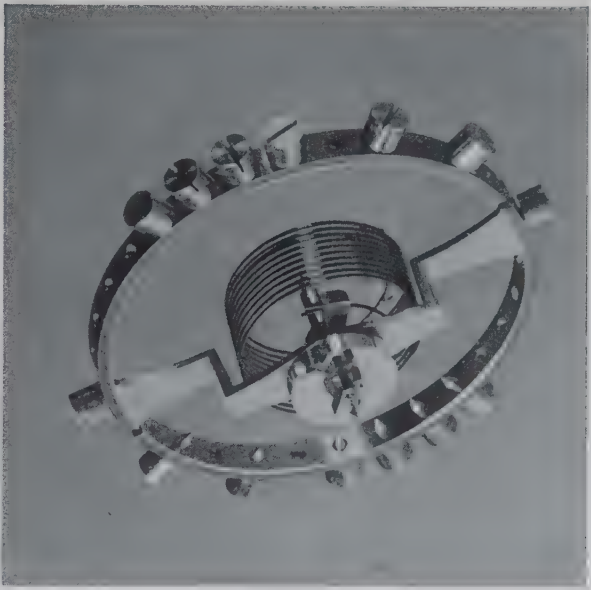
Plate 23

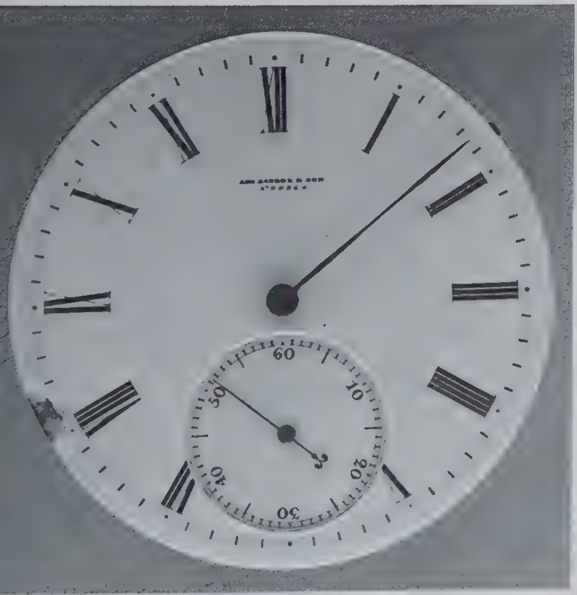
a. Cat. no. 28.
b. Cat. no. 28.
c. Cat. no. 28.
d. Cat. no. 28.
e. Cat. no. 29.
f. Cat. no. 29.


a


b


c


d


60
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20
30
40
50
e

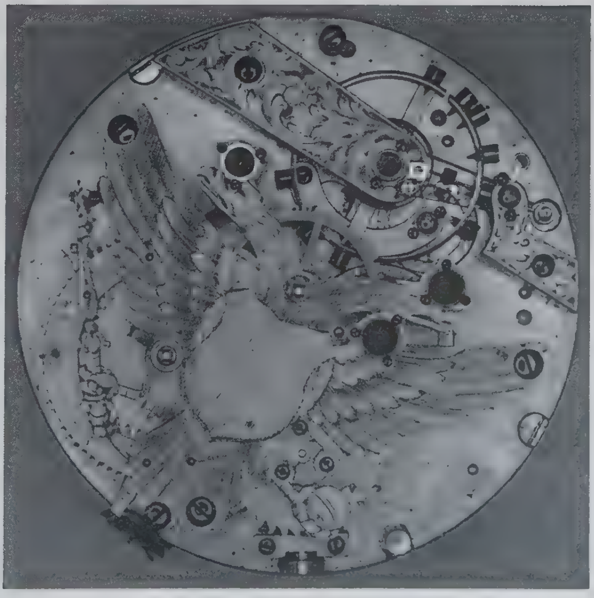
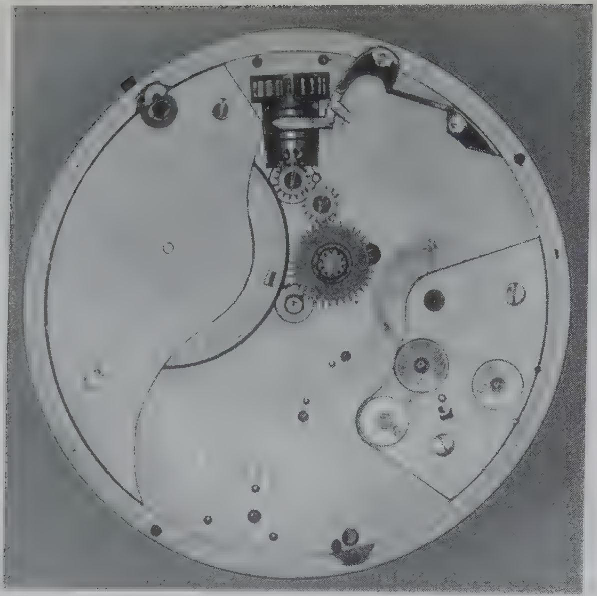
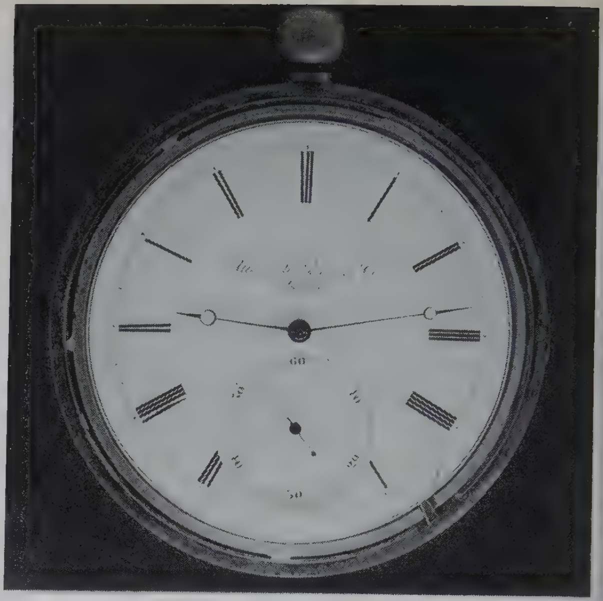
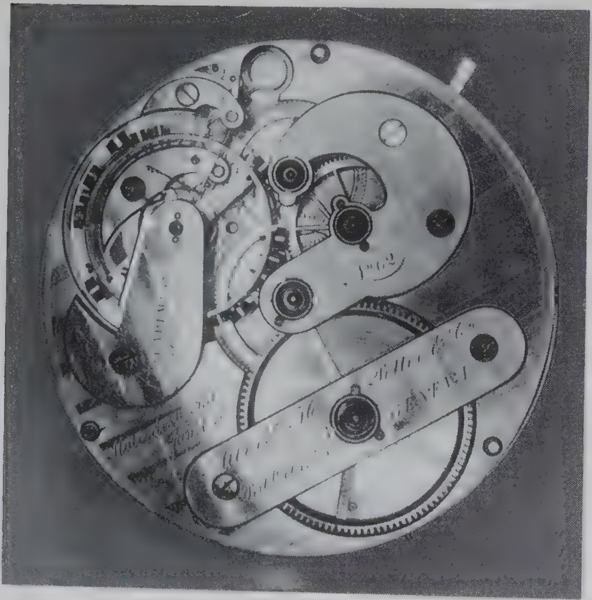

f

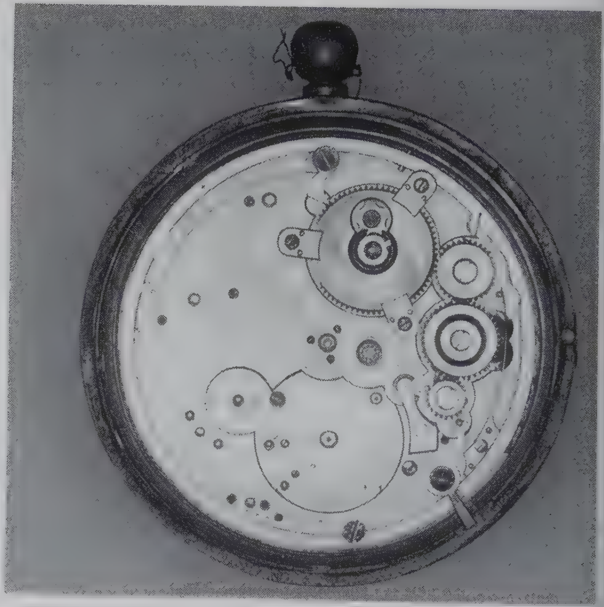
Plate 24

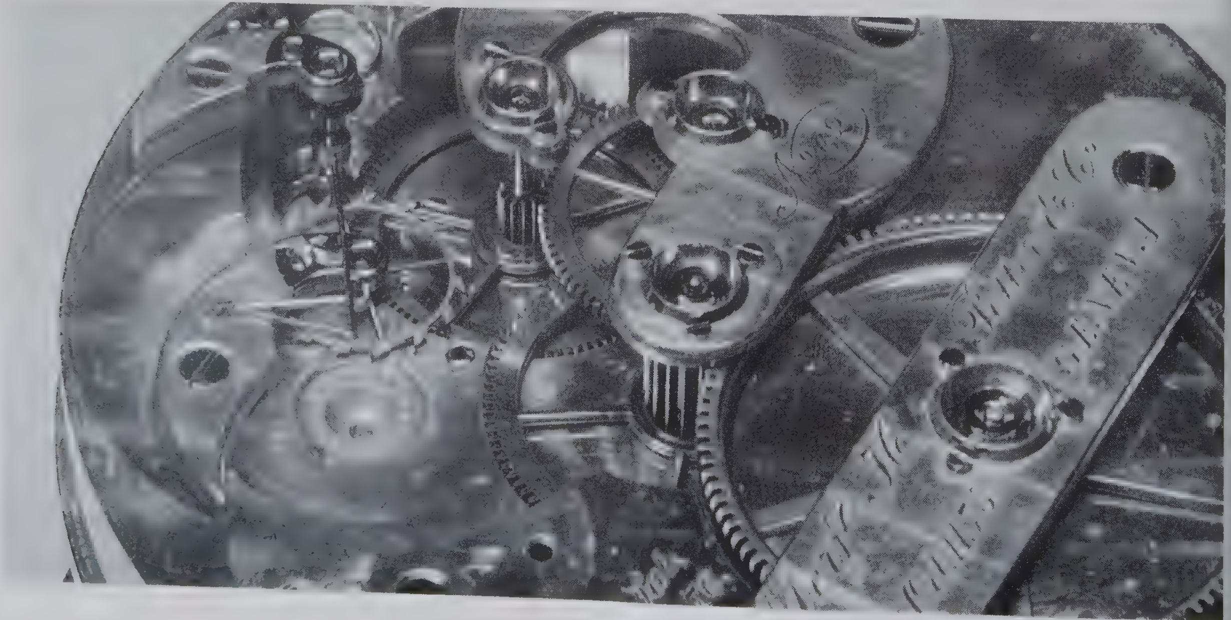
a. Cat. no. 29.
b. Cat. no. 30.
c. Cat. no. 30.
d. Cat. no. 30.
e. Cat. no. 30.


a


b


c


d


e

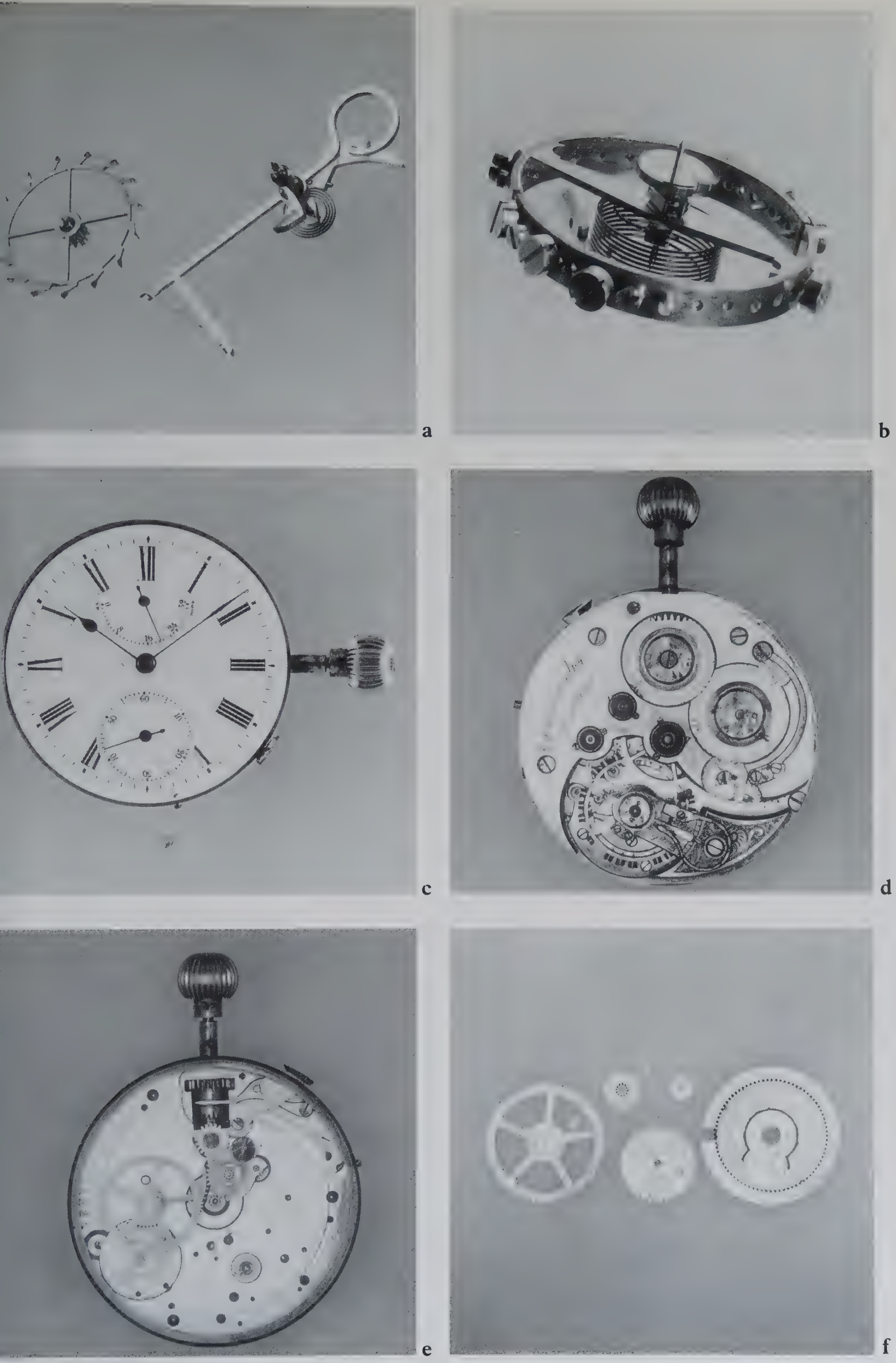
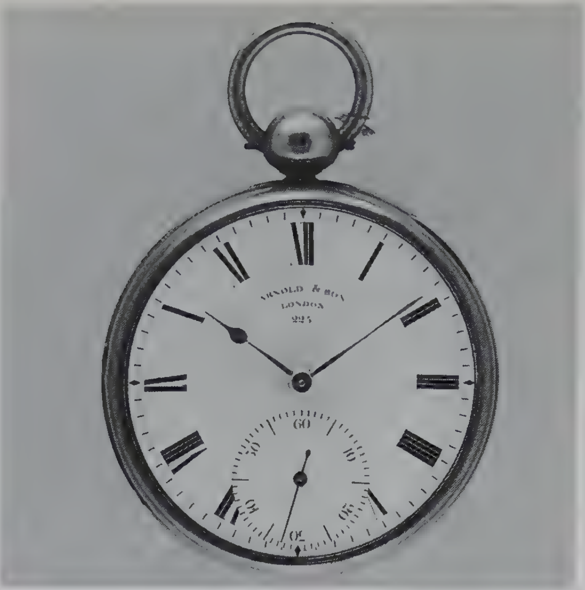


Plate 25

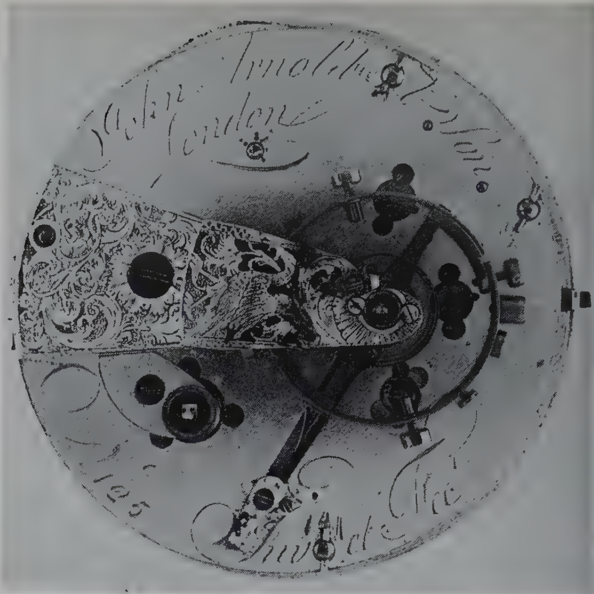
a. Cat. no. 30.
b. Cat. no. 30.
c. Cat. no. 31. The subsidiary dial below the XII is the up-and-down dial.
d. Cat. no. 31.
e. Cat. no. 31.
f. Cat. no. 31, the planar differential up-and-down work.

Plate 26

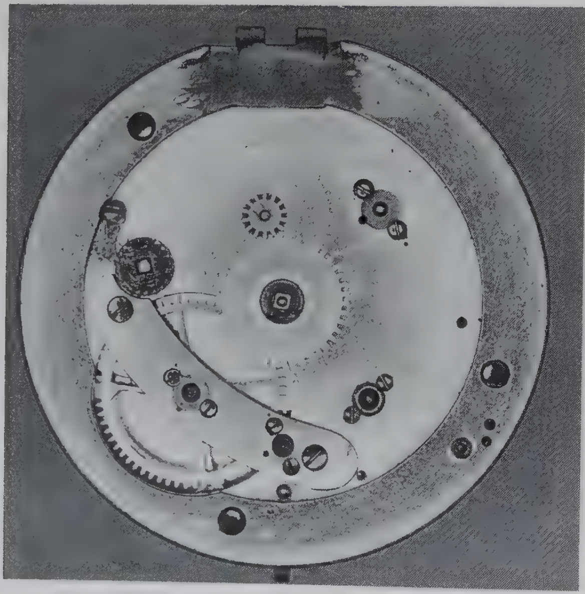
- **a.** Cat. no. 32.
- **b.** Cat. no. 32.
- **c.** Cat. no. 32.
- **d.** Cat. no. 32.
- **e.** Cat. no. 33.
- **f.** Cat. no. 33.


ARNOLD & SON
LONDON
225
60
10
20
30
40
50

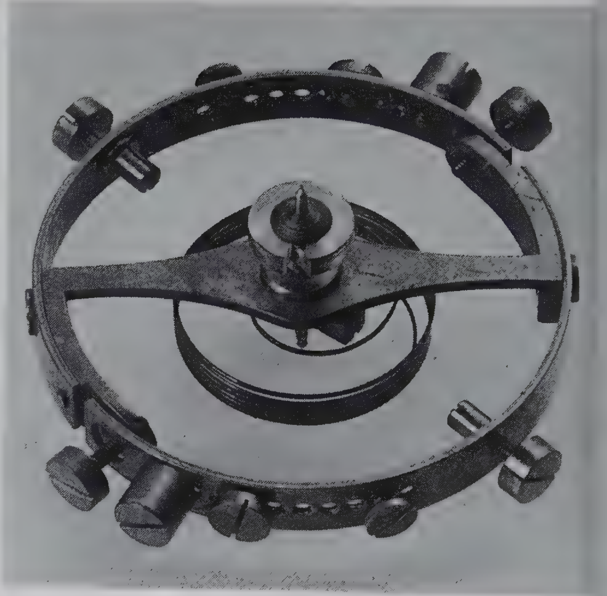
a


John Arnold & Son
London
125
Invt et Fec

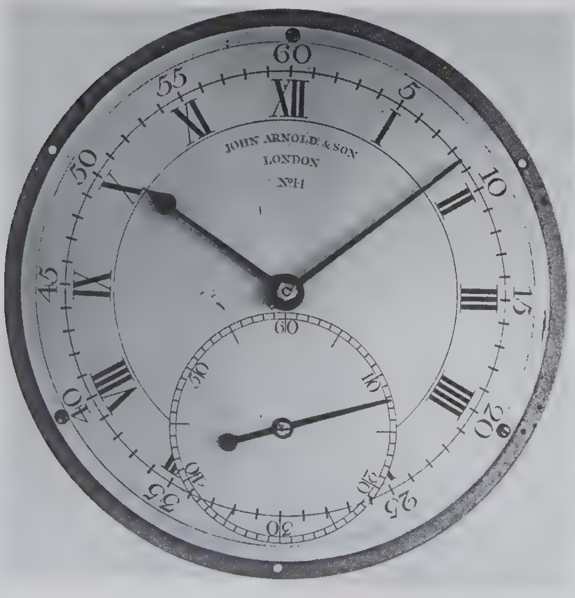
b



c



d


JOHN ARNOLD & SON
LONDON
No 11
60
5
10
15
20
25
30
35
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45
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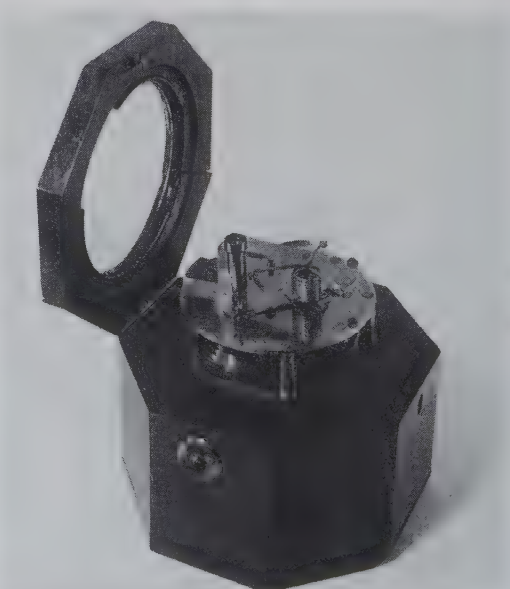
55

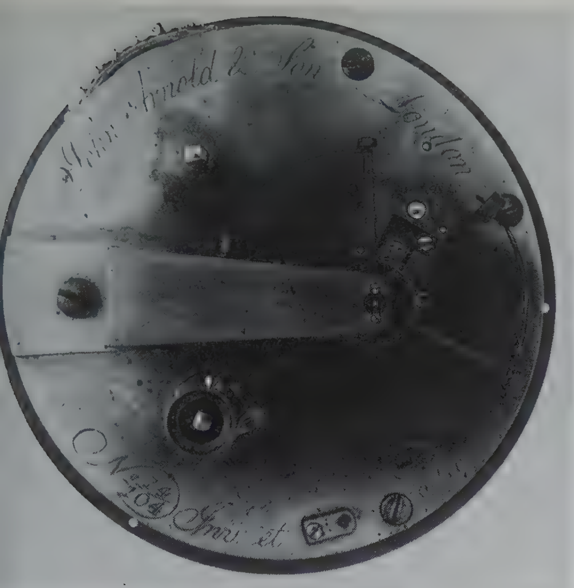
e



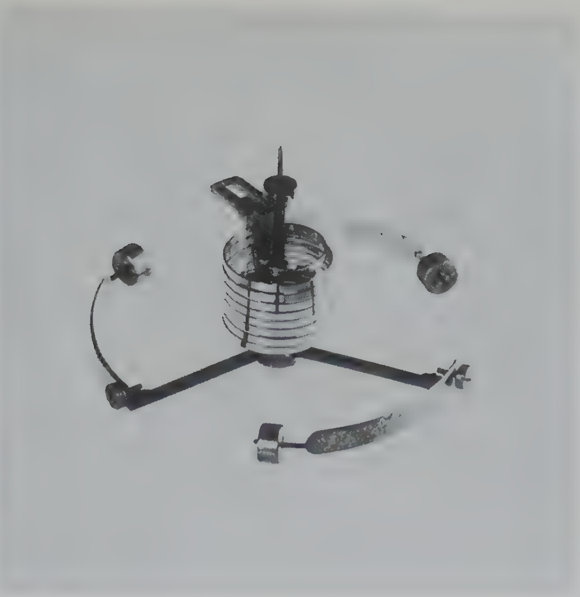
f

Plate 27

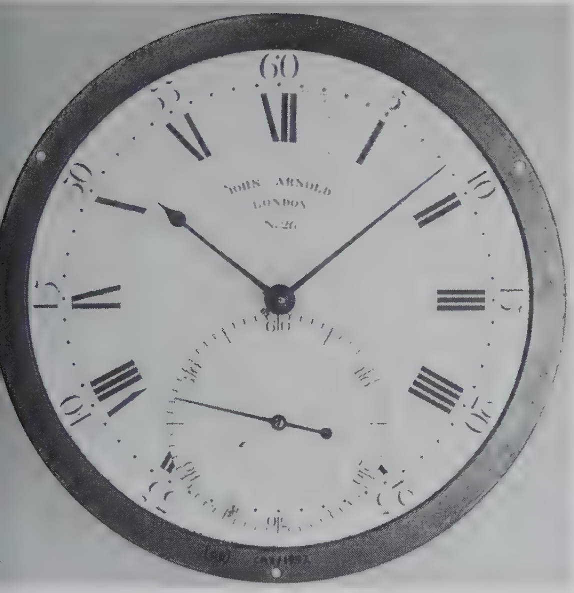
a. Cat. no. 33.
b. Cat. no. 33.
c. Cat. no. 34.
d. Cat. no. 34.
e. Cat. no. 34.
f. Cat. no. 34.


John Arnold & Son
London
No 204
Invt et

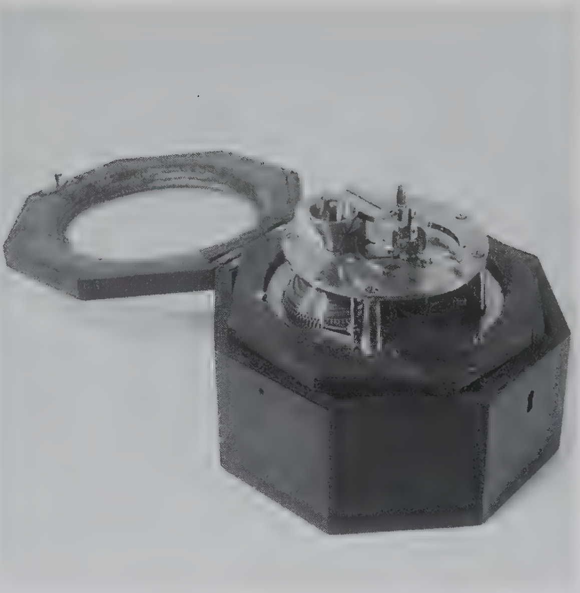
a



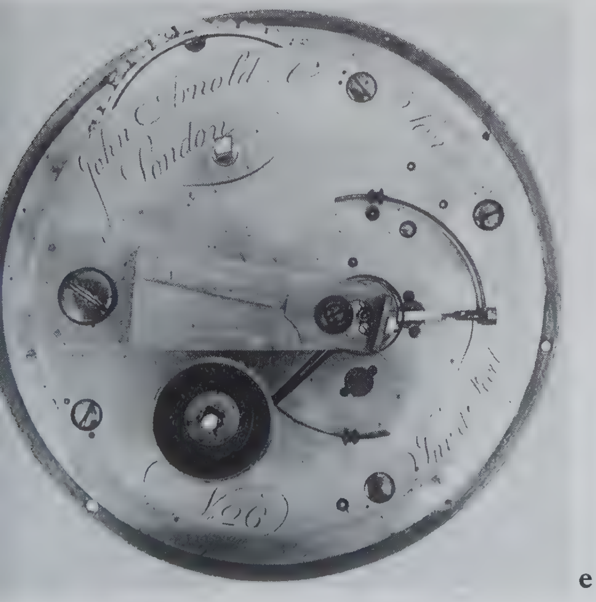
b


JOHN ARNOLD
LONDON
N. 26

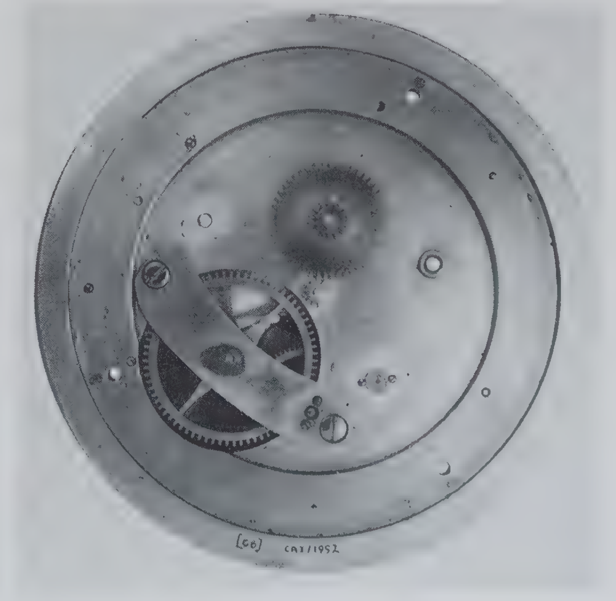
c



d


John Arnold & Son
London
No 26
Invt et

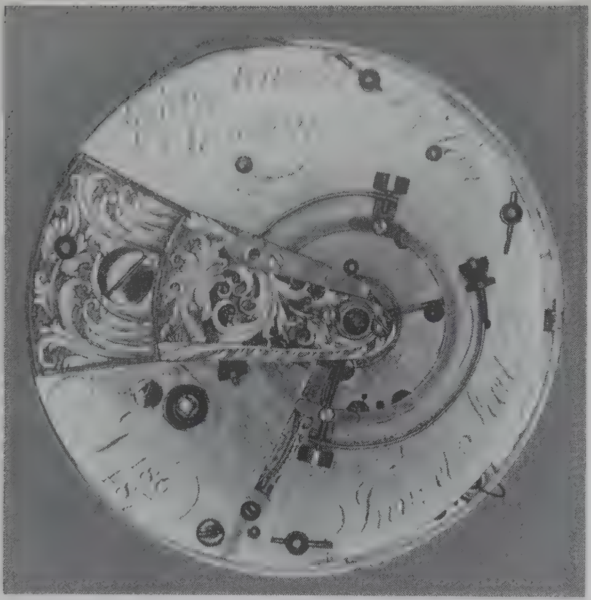
e

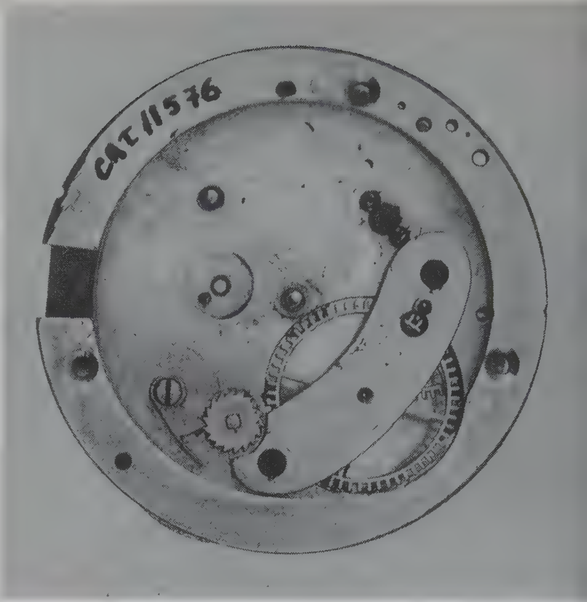


f

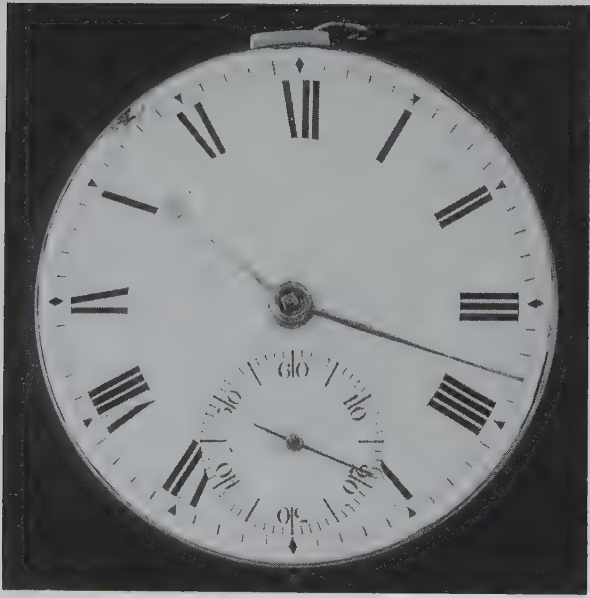
Plate 28

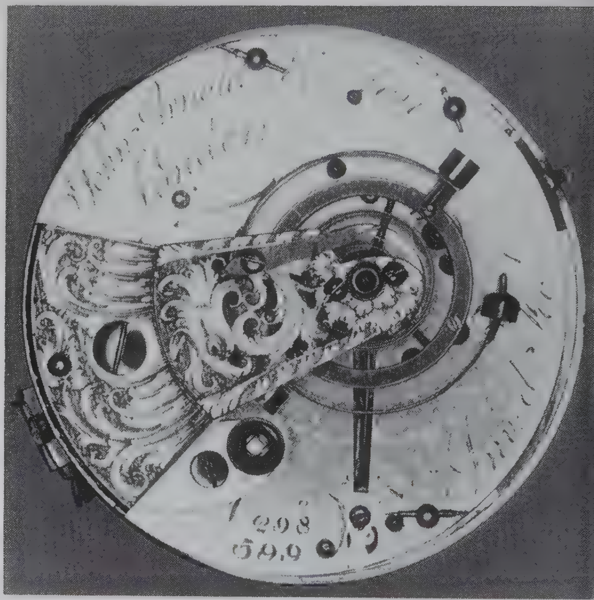
a. Cat. no. 35.
b. Cat. no. 35.
c. Cat. no. 36.
d. Cat. no. 36.
e. Cat. no. 36.
f. Cat. no. 36.


a

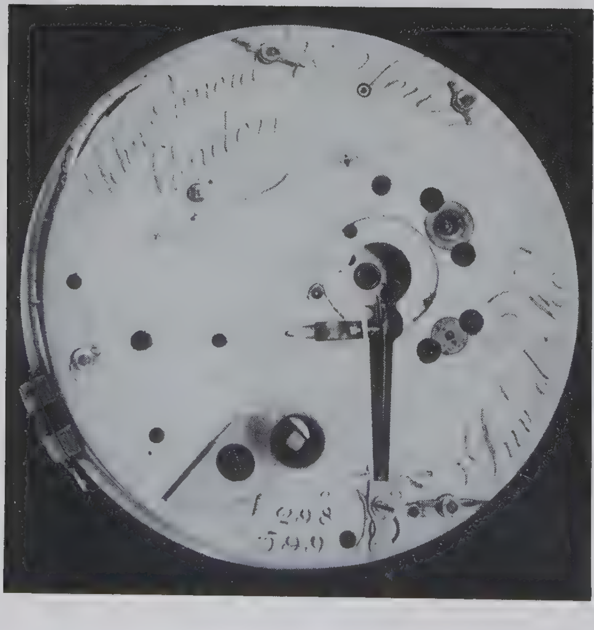


b


c



d



e

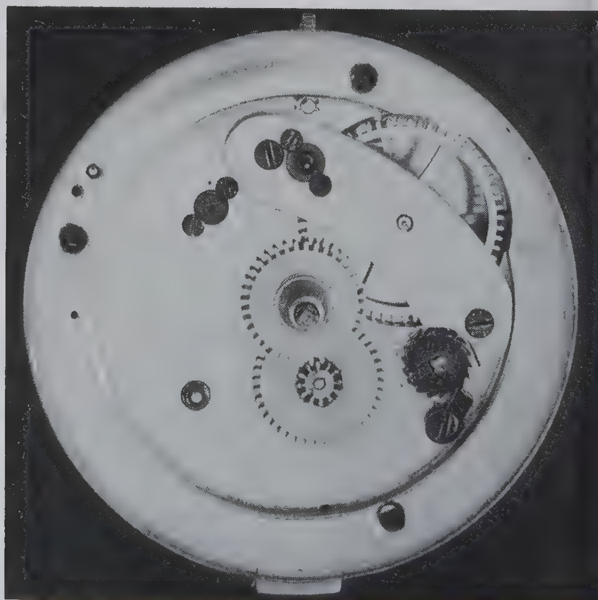
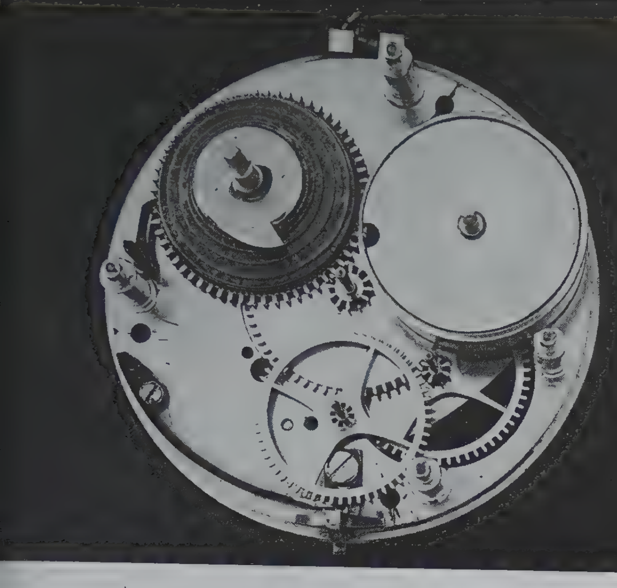
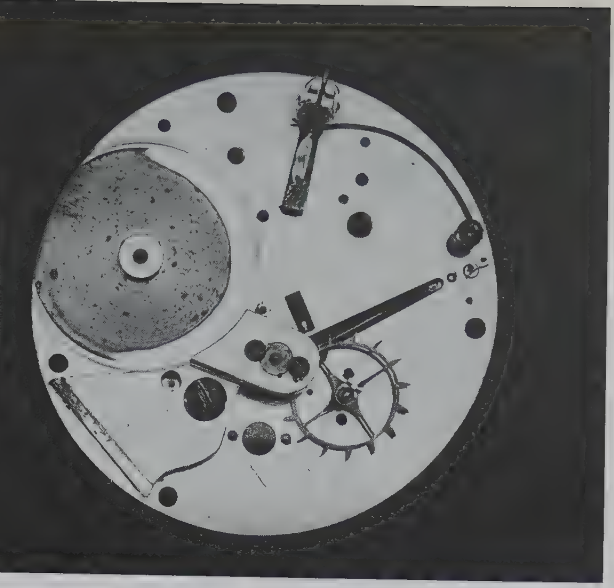

f

Plate 29

a. Cat. no. 36.
b. Cat. no. 36.
c. Cat. no. 36.
d. Cat. no. 37.
e. Cat. no. 37.
f. Cat. no. 37.

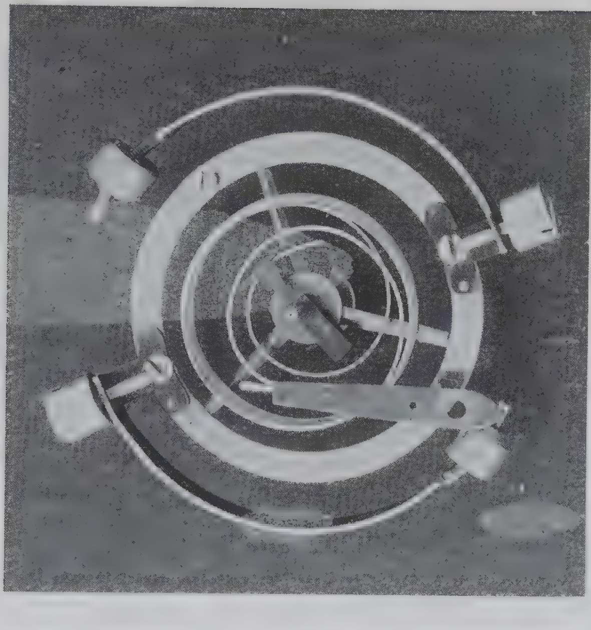


a

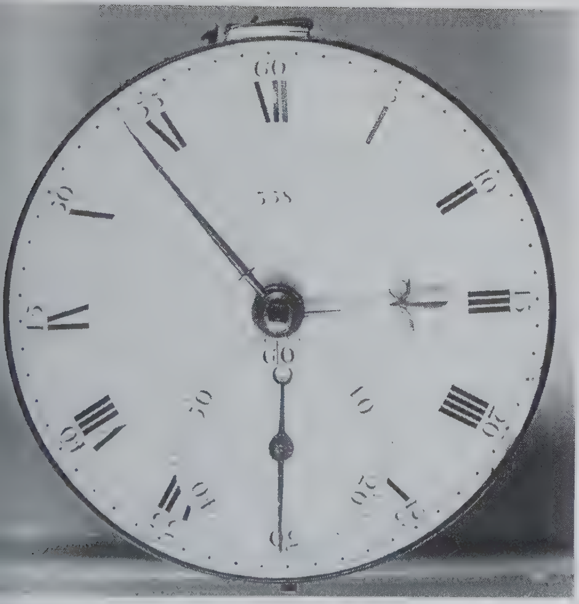


b

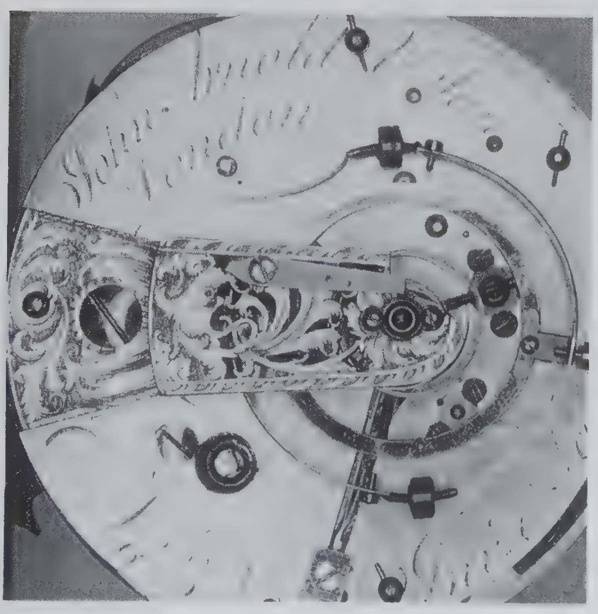
c



d



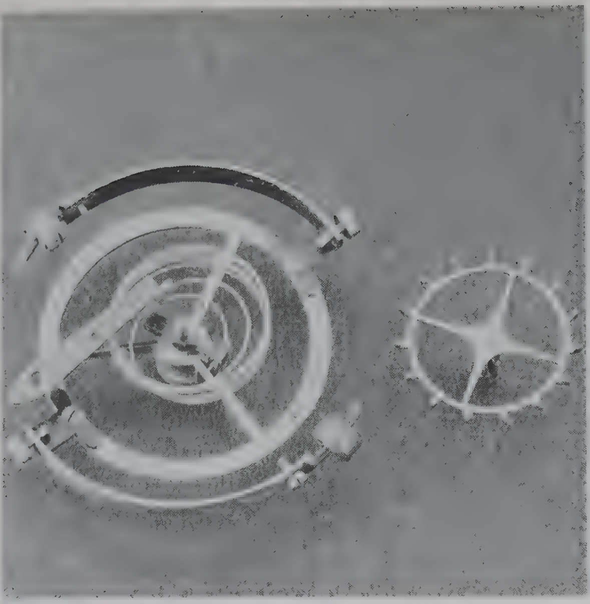
e

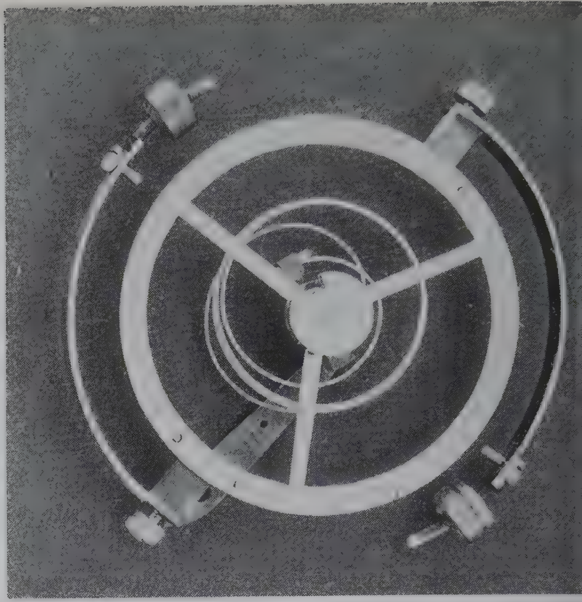

John Arnold
London

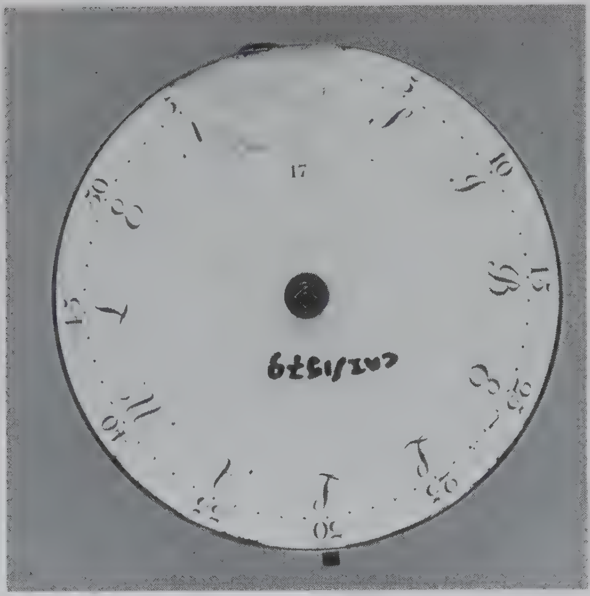
f

Plate 30

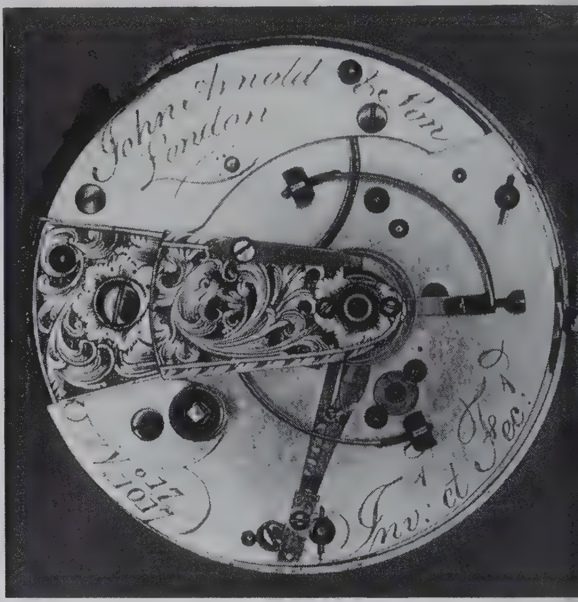
a. Cat. no. 37.
b. Cat. no. 37.
c. Cat. no. 38.
d. Cat. no. 38.
e. Cat. no. 39.
f. Cat. no. 39.

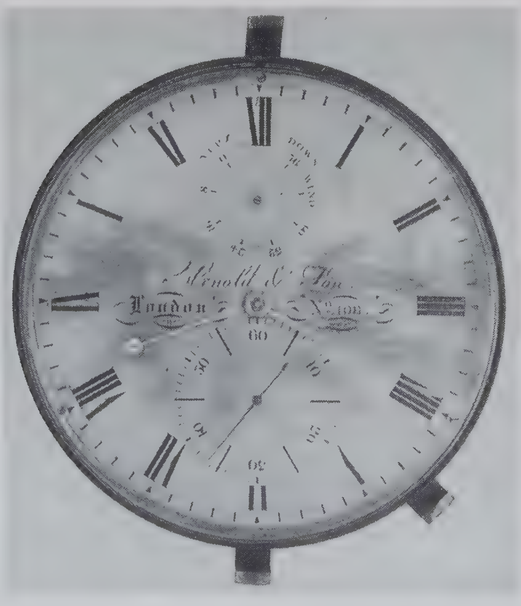

a


b



c


John Arnold & Son
London
No 17
Inv: et Fec.
d


Arnold & Son
London
No 108
e

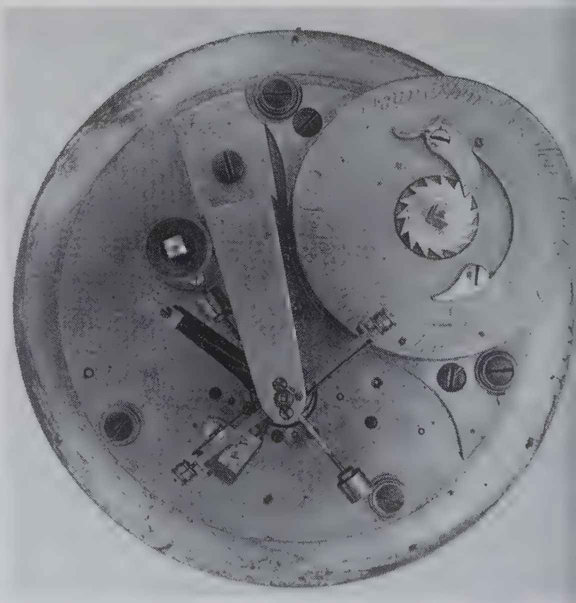
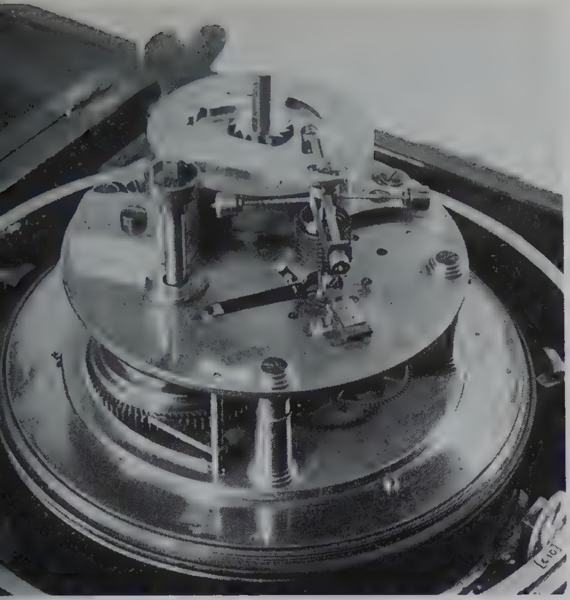
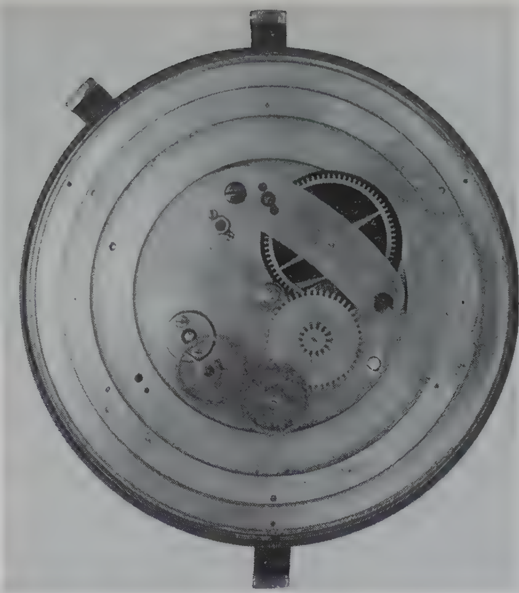
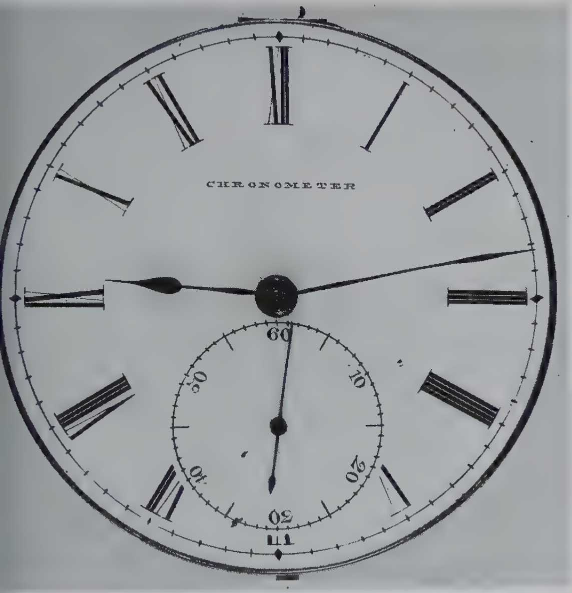

f

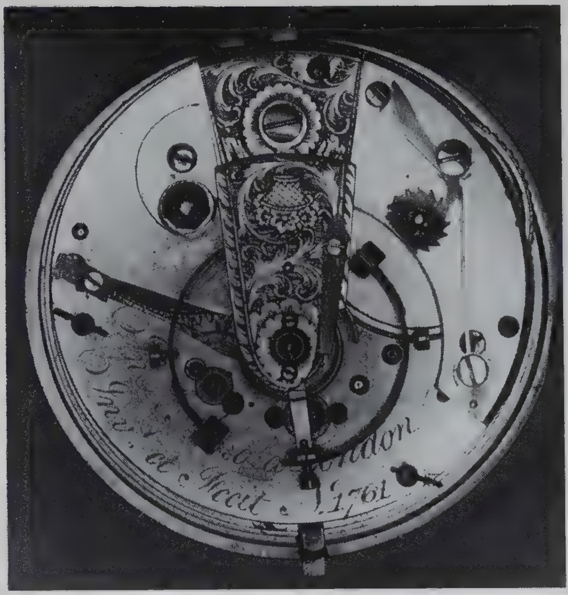
Plate 31

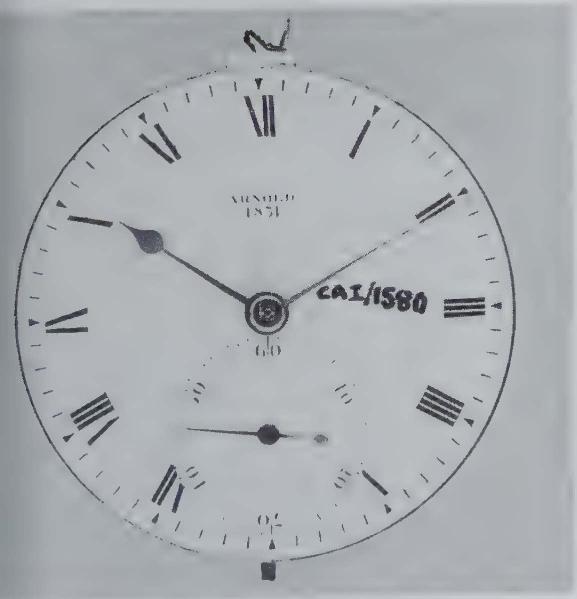
- **a.** Cat. no. 39.
- **b.** Cat. no. 39.
- **c.** Cat. no. 40.
- **d.** Cat. no. 40.
- **e.** Cat. no. 41.
- **f.** Cat. no. 41.


a


b


CHRONOMETER
c


London
1761
d


ARNOLD
1831
CAI/1580
e

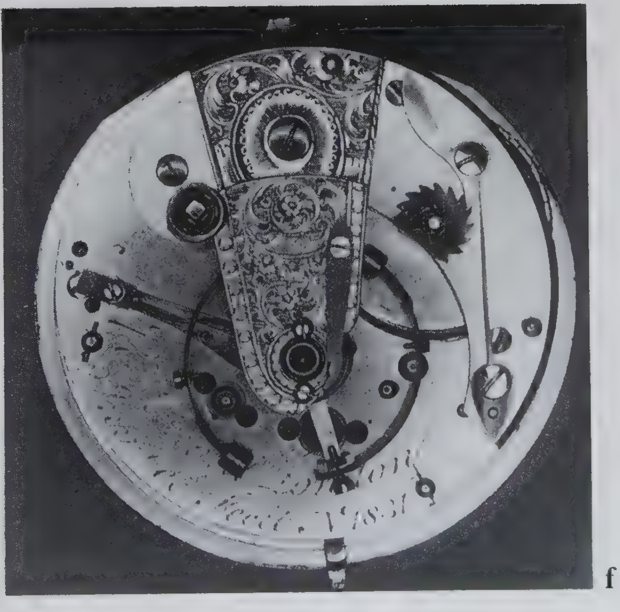
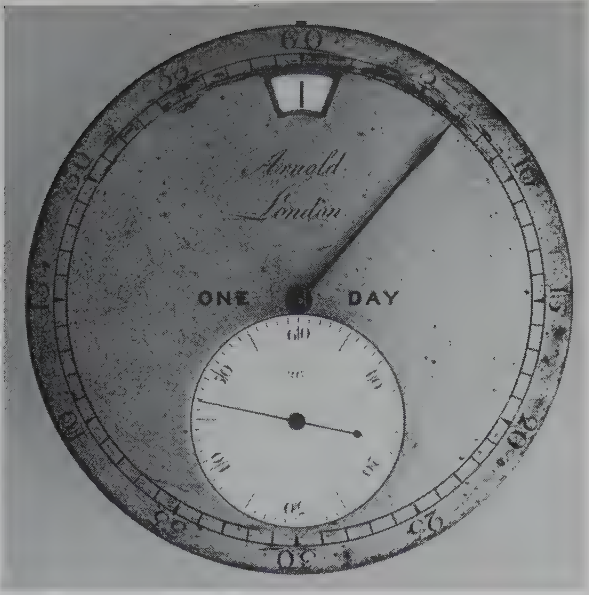
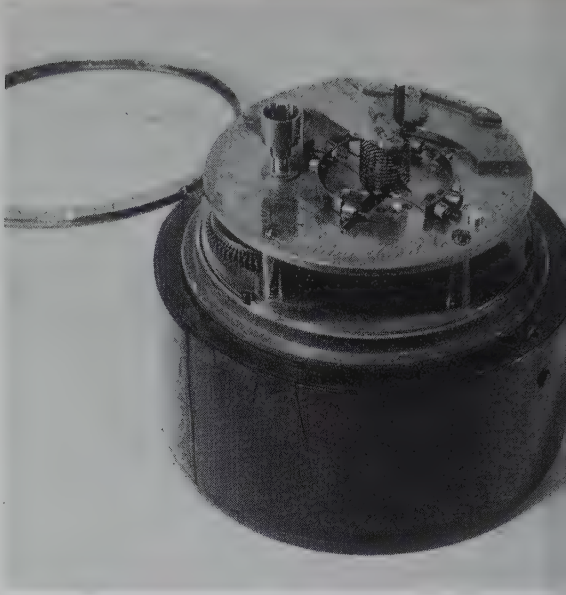

f

Plate 32

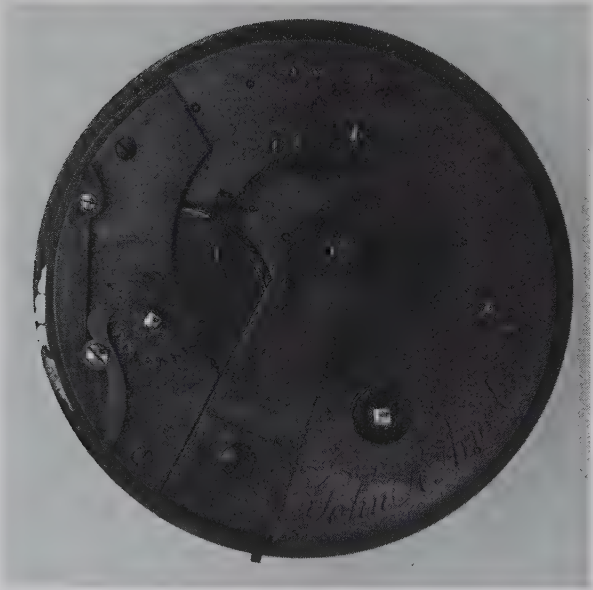
a. Cat. no. 42.
b. Cat. no. 42.
c. Cat. no. 42.
d. Cat. no. 42, the main dial removed to show the hour dial.
e. Cat. no. 43.
f. Cat. no. 43.


Arnold
London
ONE
DAY

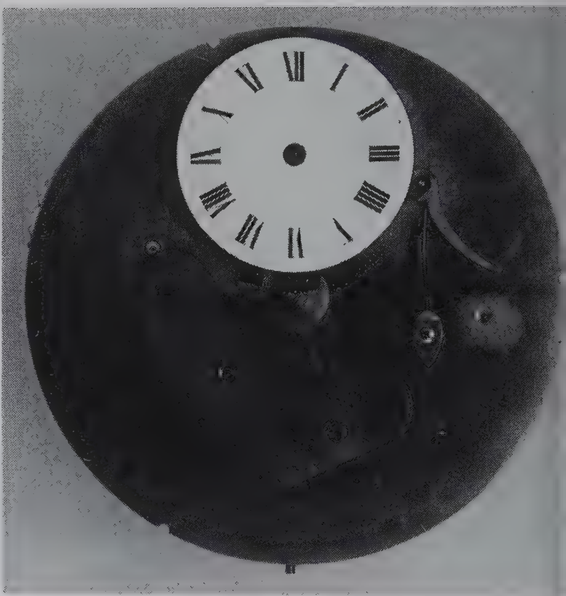
a



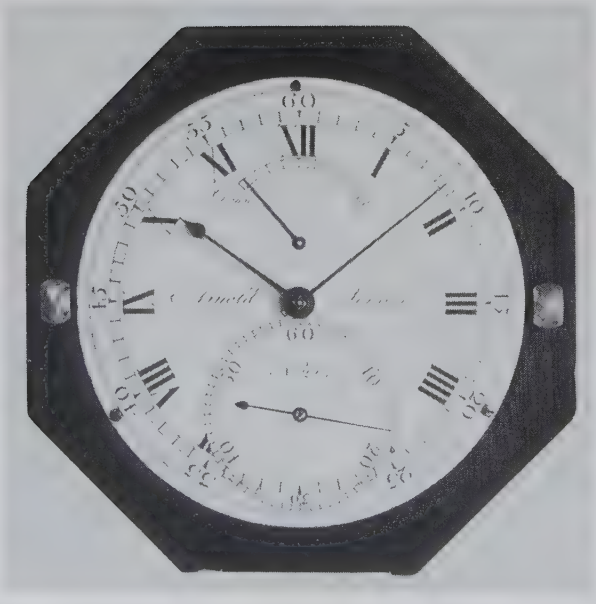
b



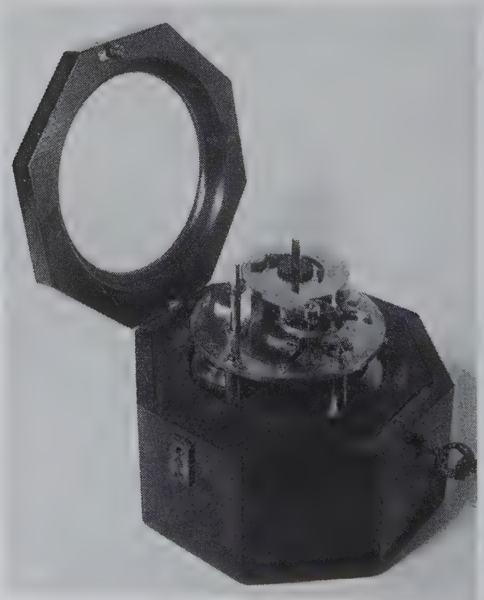
c



d


Arnold
London

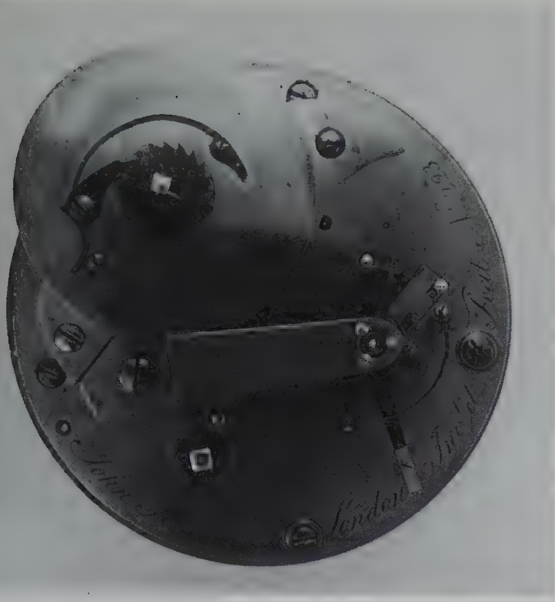
e

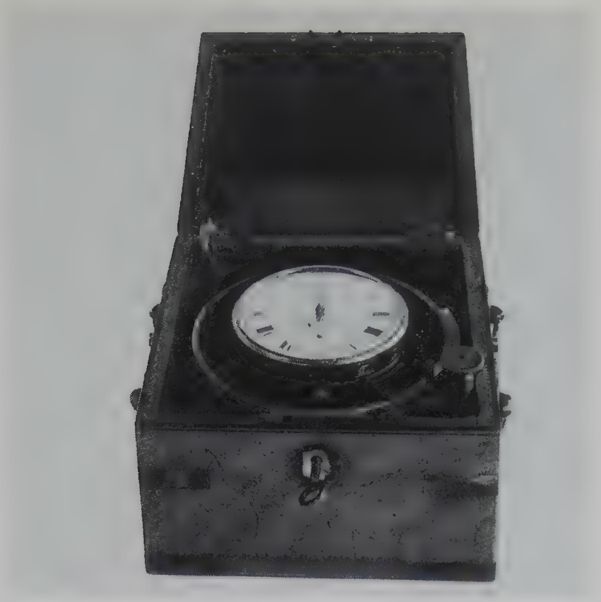


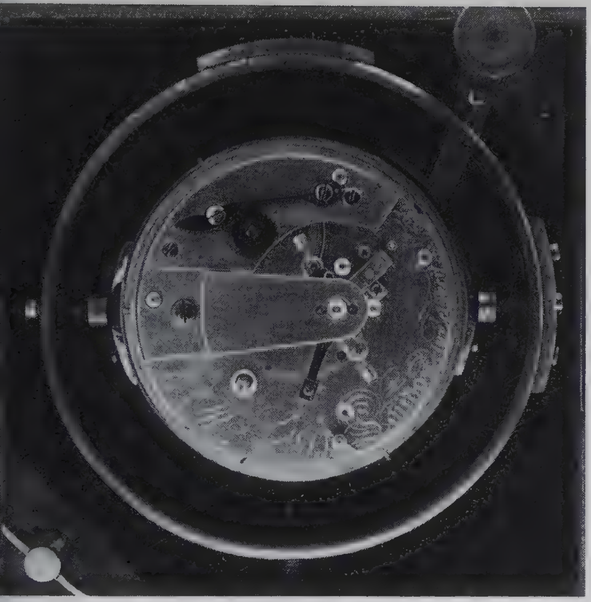
f

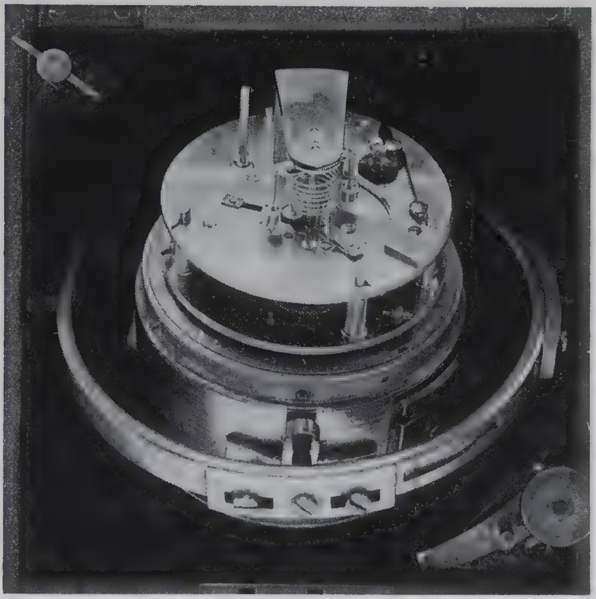
Plate 33

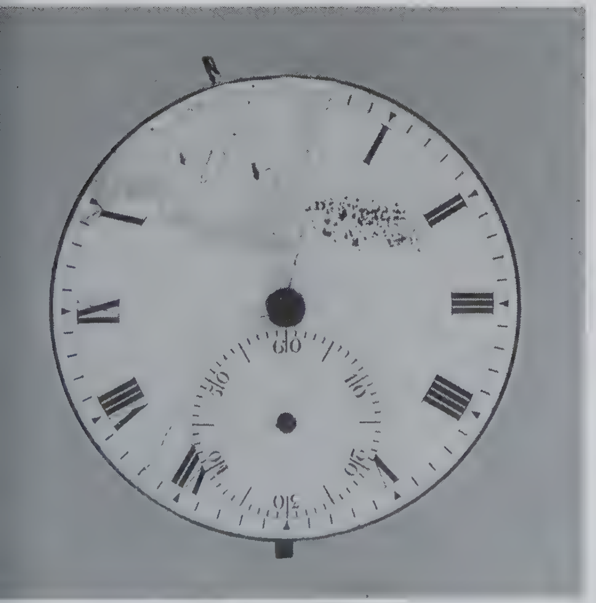
a. Cat. no. 43.
b. Cat. no. 43A.
c. Cat. no. 43A.
d. Cat. no. 43A.
e. Cat. no. 44.
f. Cat. no. 44.


a


b


c


d


e

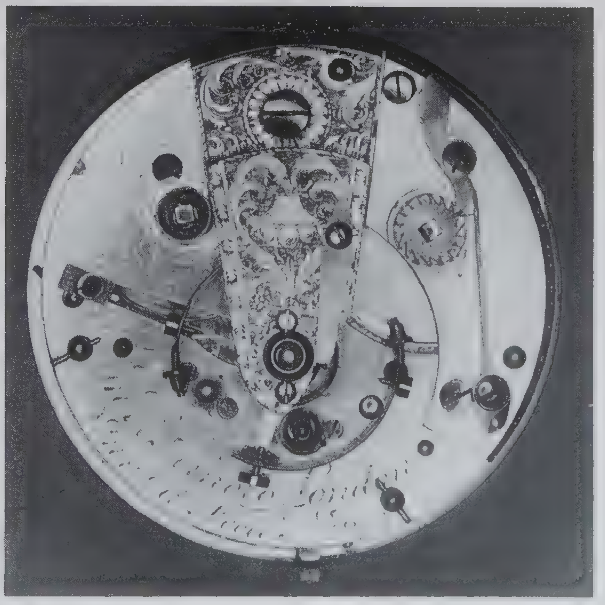
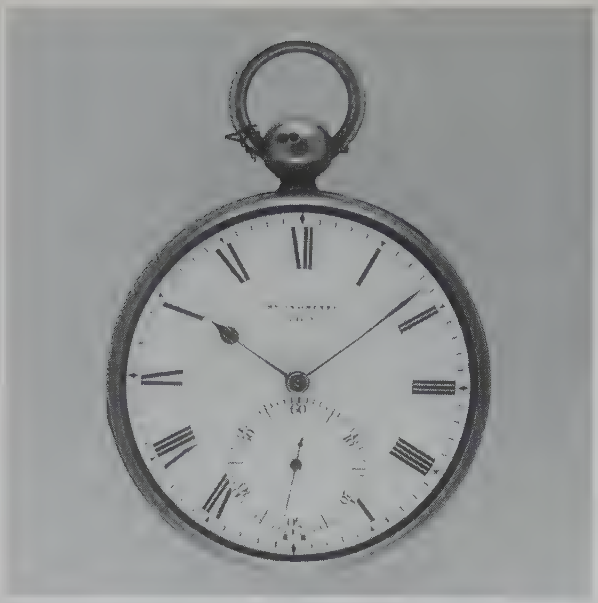
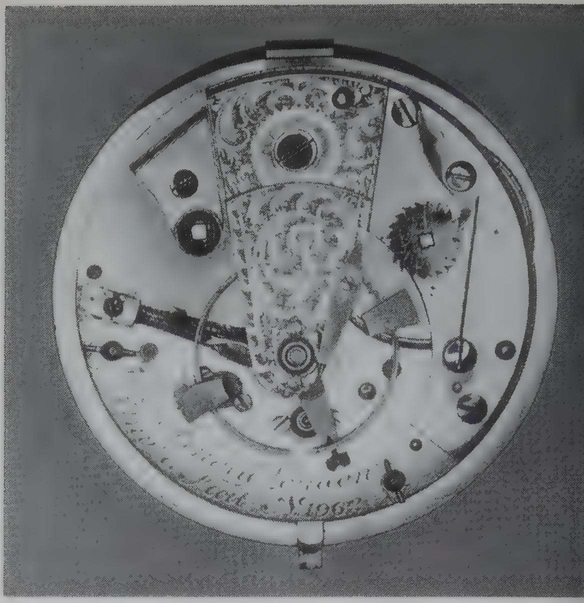
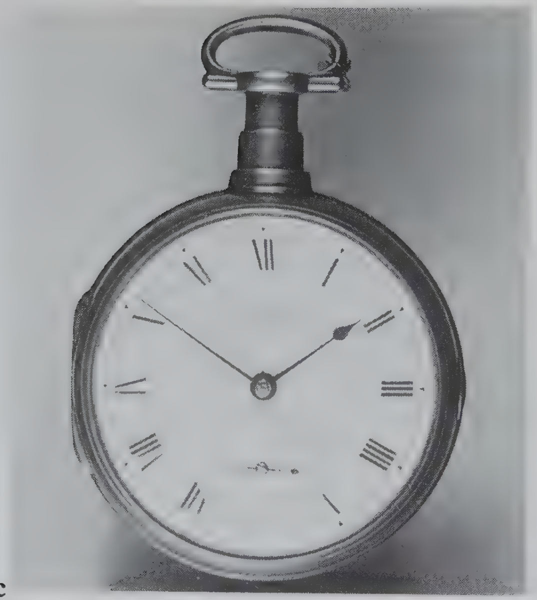

f

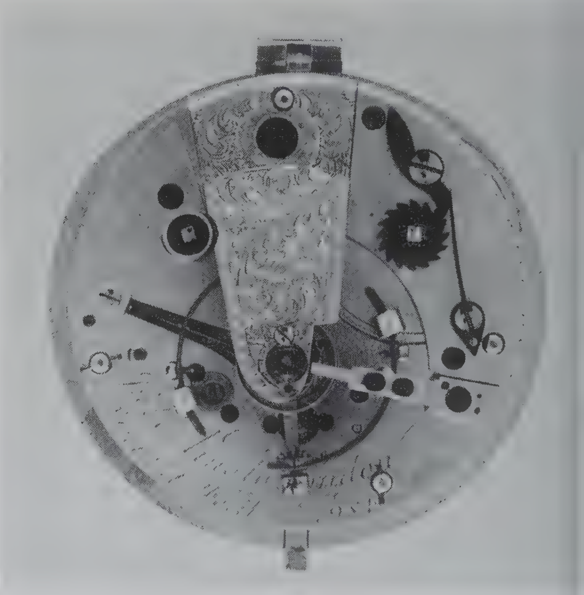
Plate 34

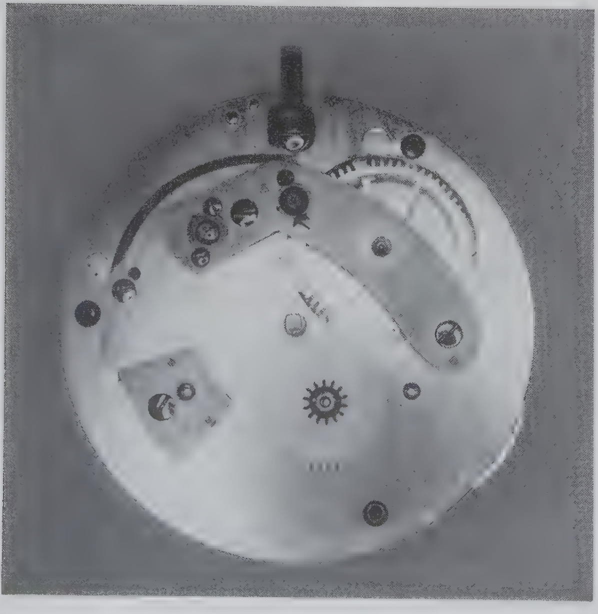
a. Cat. no. 45.
b. Cat. no. 45.
c. Cat. no. 46.
d. Cat. no. 46.
e. Cat. no. 46.
f. Cat. no. 46.


a


b


c


d


e

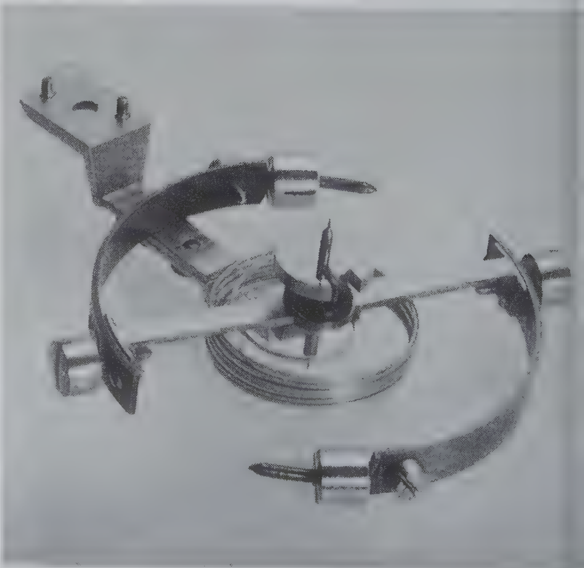
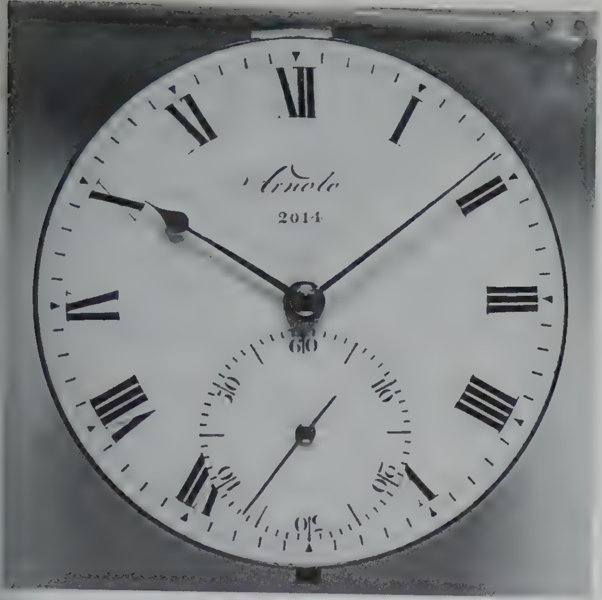
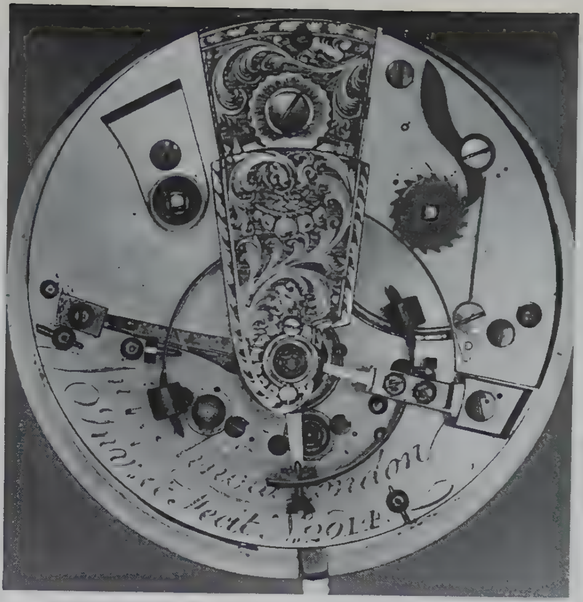

f

Plate 35

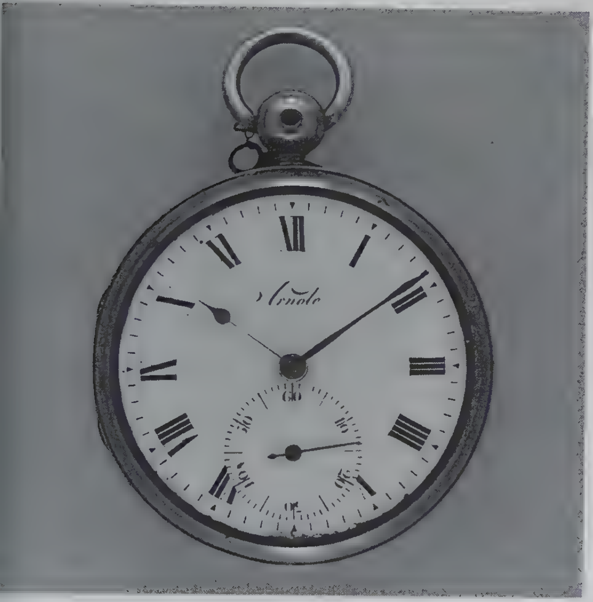
a. Cat. no. 47.
b. Cat. no. 47.
c. Cat. no. 48.
d. Cat. no. 48.
e. Cat. no. 49.
f. Cat. no. 49.


Arnold
2014

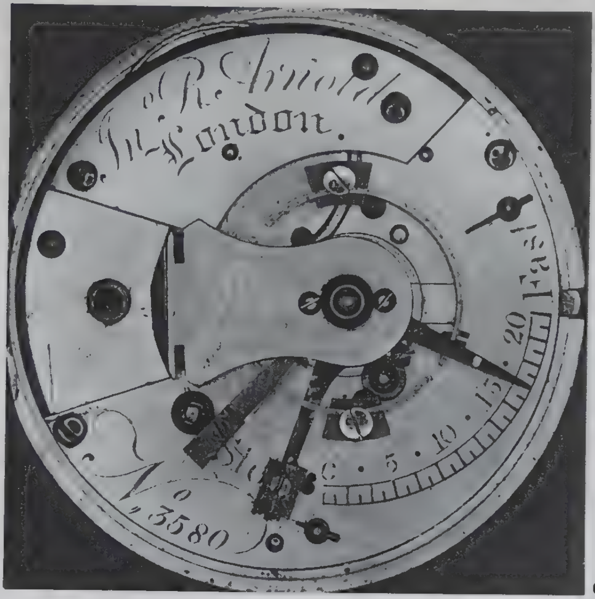
a


Arnold London
Invt. et Fecit. No 2014

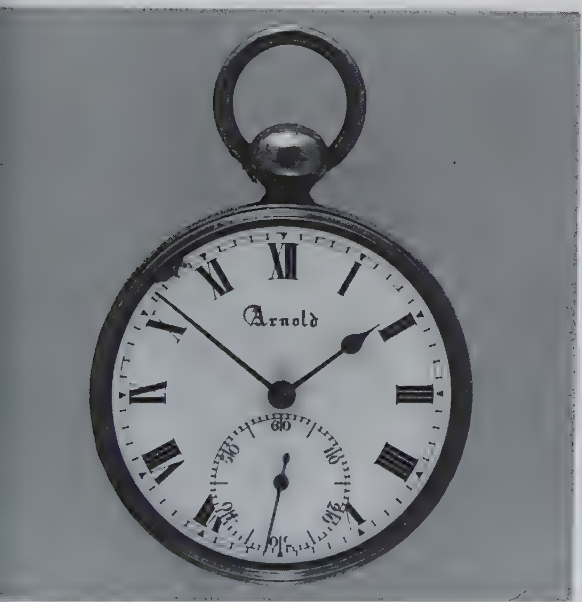
b



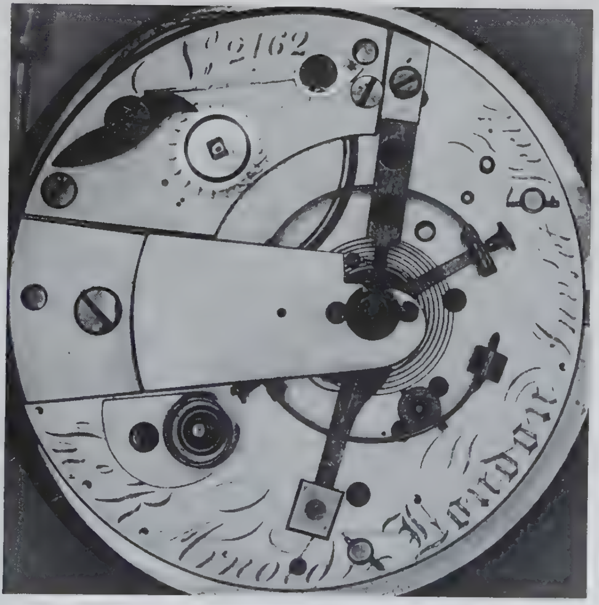
c


R. Arnold
In London.
Fast
Slow
No 3580
5
10
15
20

d



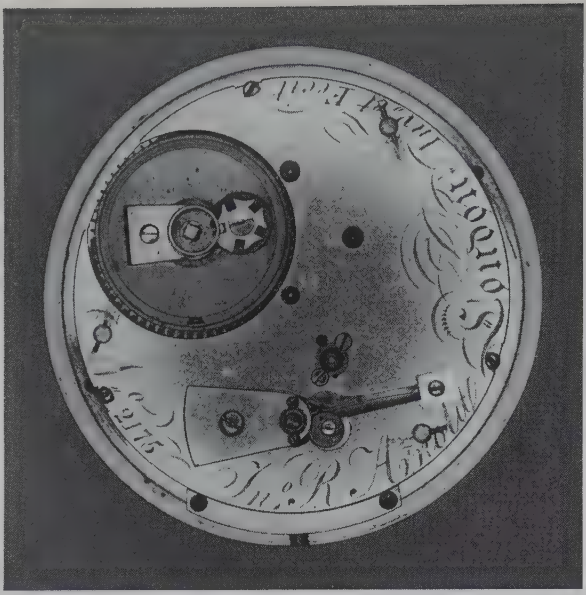
e


No 2162
Invt et Fecit
R. Arnold
London

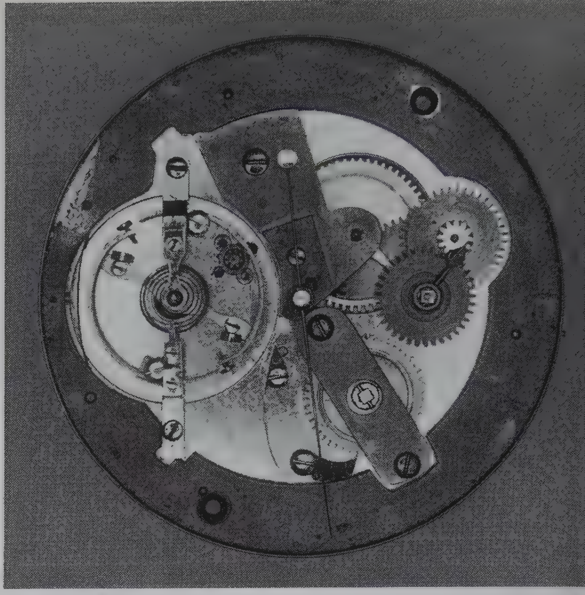
f

Plate 36

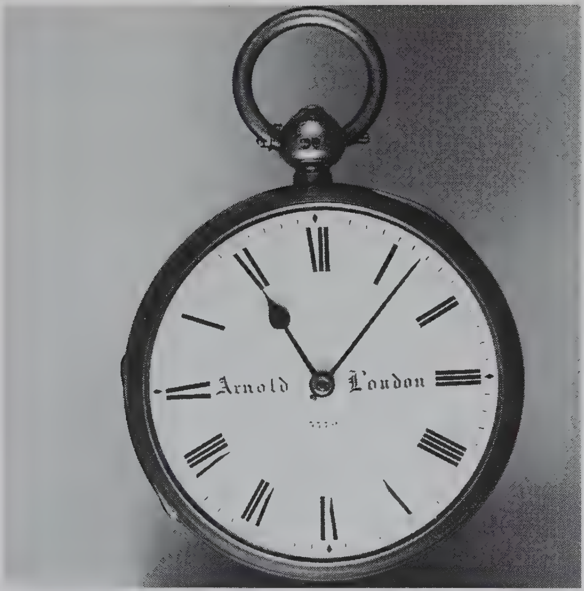
a. Cat. no. 50. This odd watch is built upside-down.
b. Cat. no. 50. The balance would have been visible through a hole in the dial which is now missing. The hour and minute hands are at '3 o'clock'.
c. Cat. no. 51.
d. Cat. no. 51.
e. Cat. no. 52.
f. Cat. no. 52.


Jnº R. Arnold
London
2175

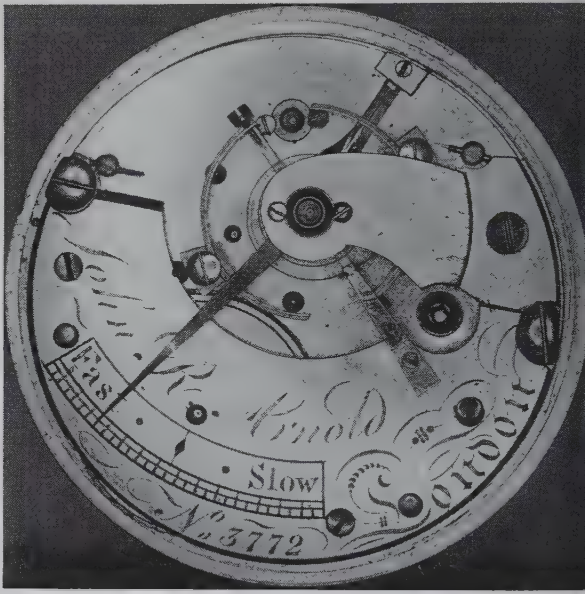
a



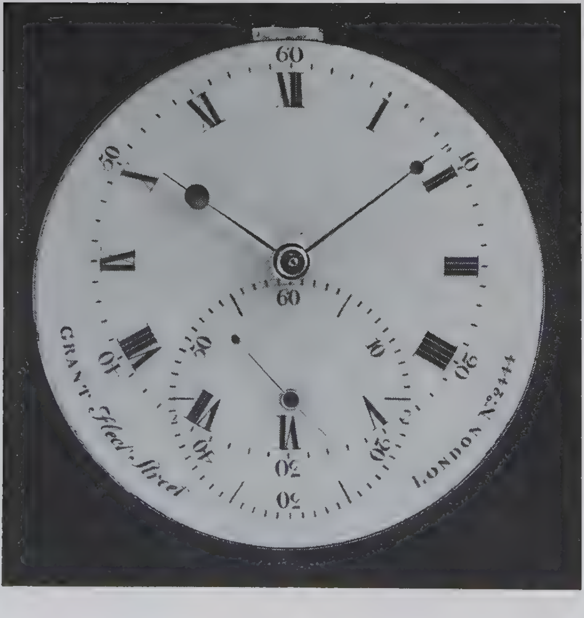
b


Arnold London

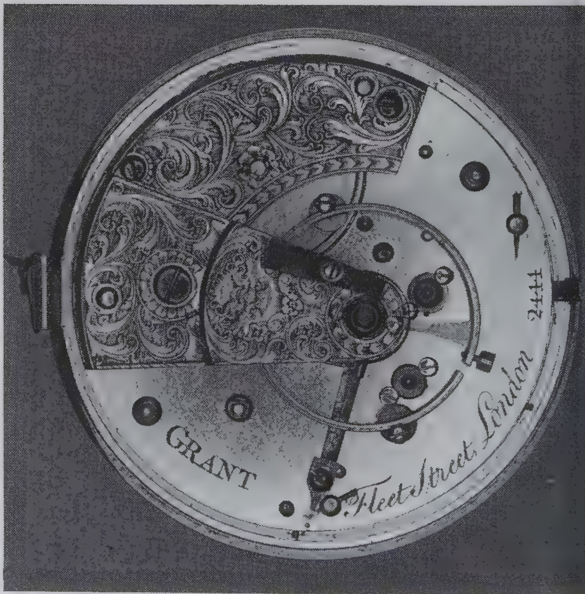
c


Jnº R. Arnold
London
Fas
Slow
Nº 3772

d


60
10
20
30
40
50
GRANT Fleet Street
LONDON Nº 2444

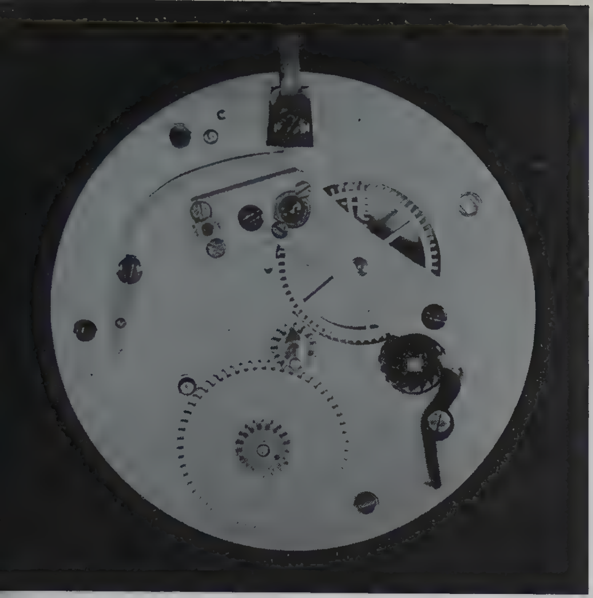
e


GRANT
Fleet Street, London
2444

f

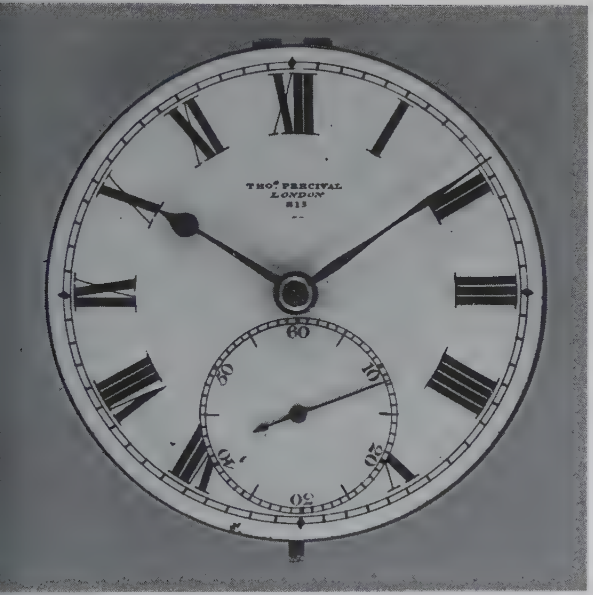
Plate 37

a. Cat. no. 52.
b. Cat. no. 52.
c. Cat. no. 53.
d. Cat. no. 53.
e. Cat. no. 53.



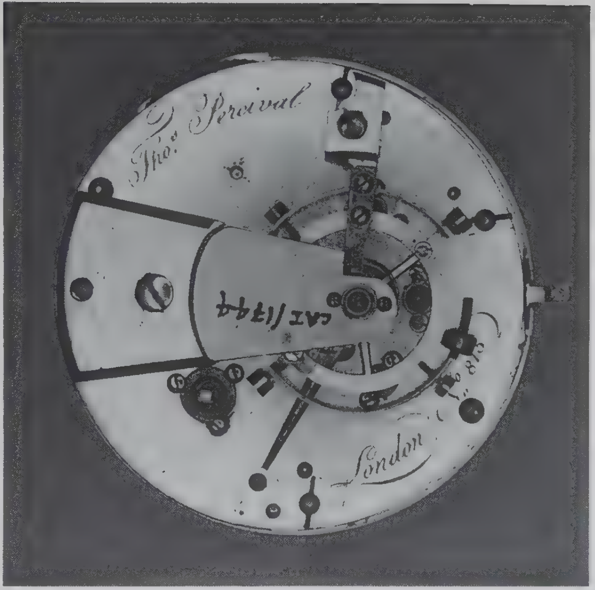
a

b



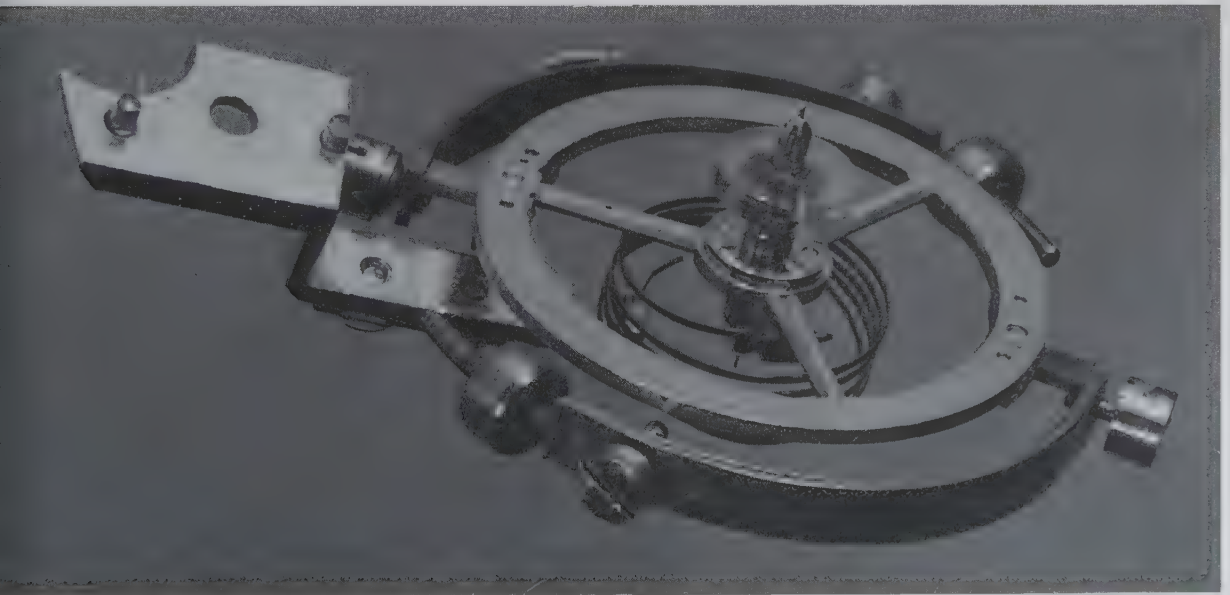
c

THOS PERCIVAL
LONDON
813
60
10
20
30
40
50



d

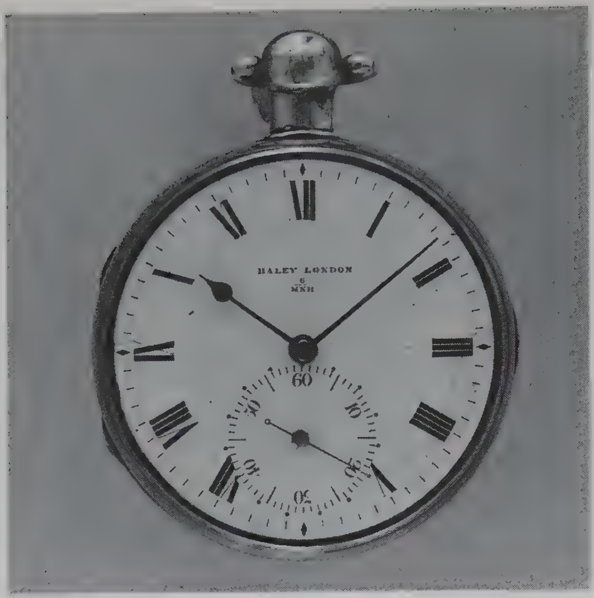
Thos Percival
CAT 1/1744
London
No 813



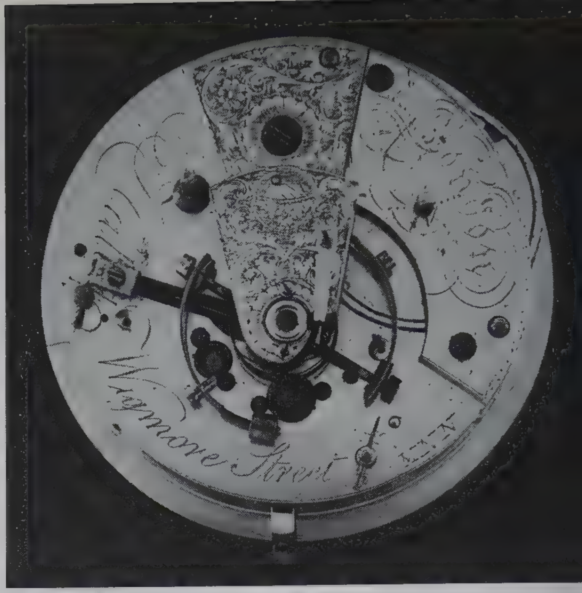
e

Plate 38

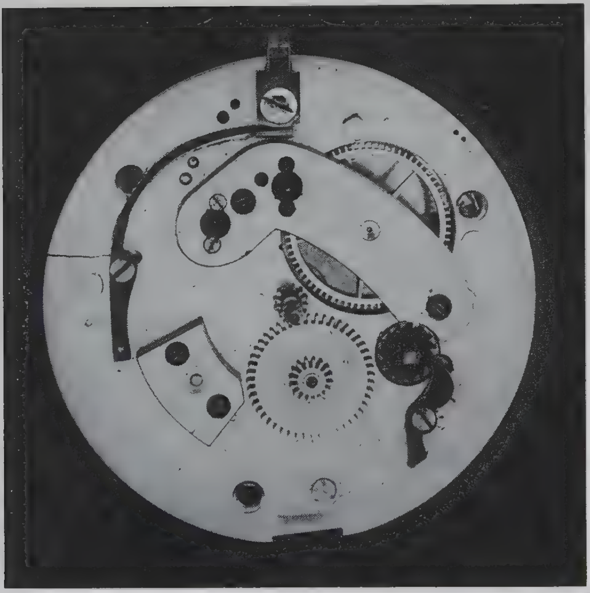
a. Cat. no. 54.
b. Cat. no. 54.
c. Cat. no. 54.
d. Cat. no. 54.
e. Cat. no. 55.
f. Cat. no. 55.


HALEY LONDON
6
MNH
60
10
20
30
40
50

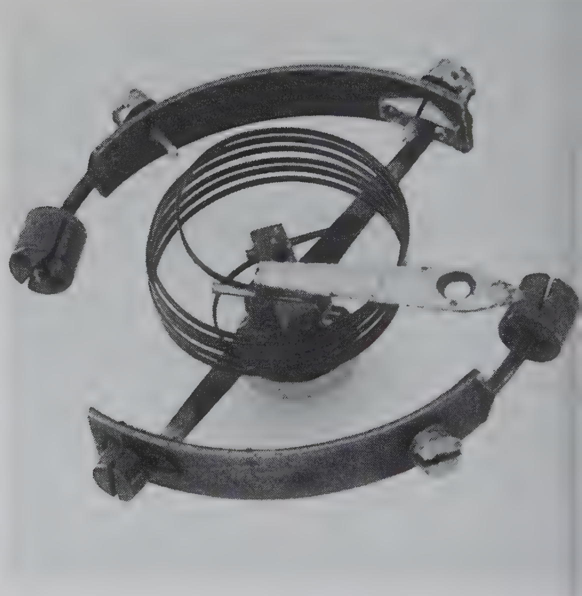
a


Wigmore Street

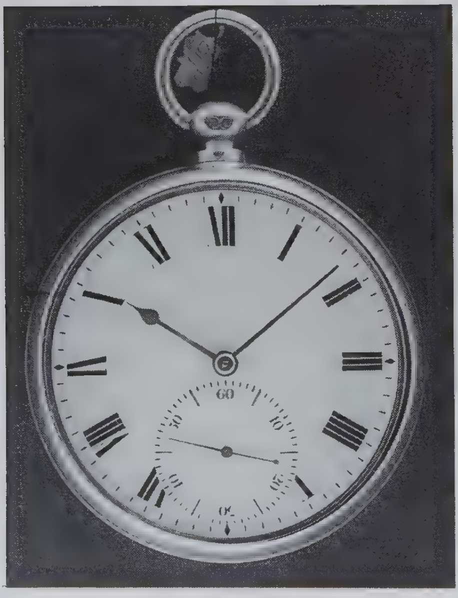
b



c



d


60
10
20
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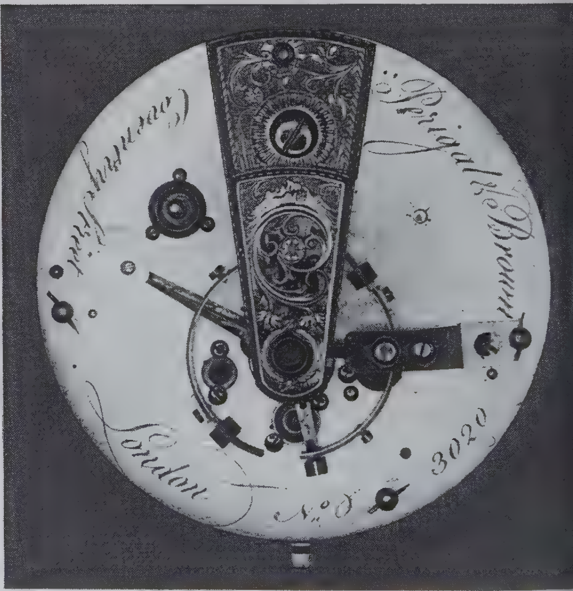
40
50

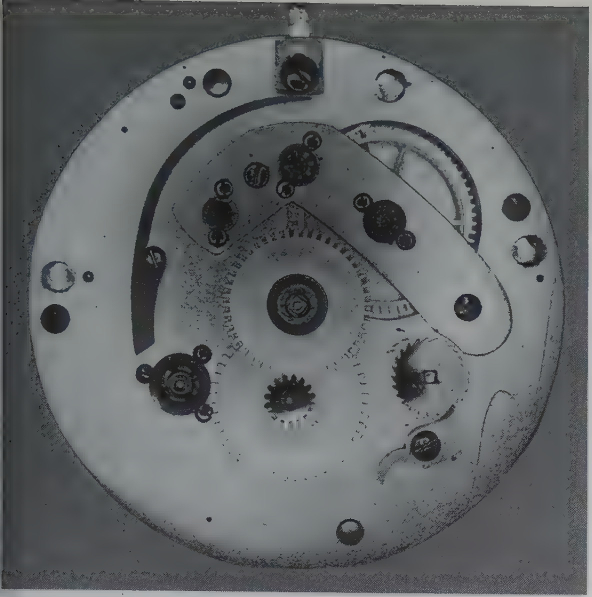
e

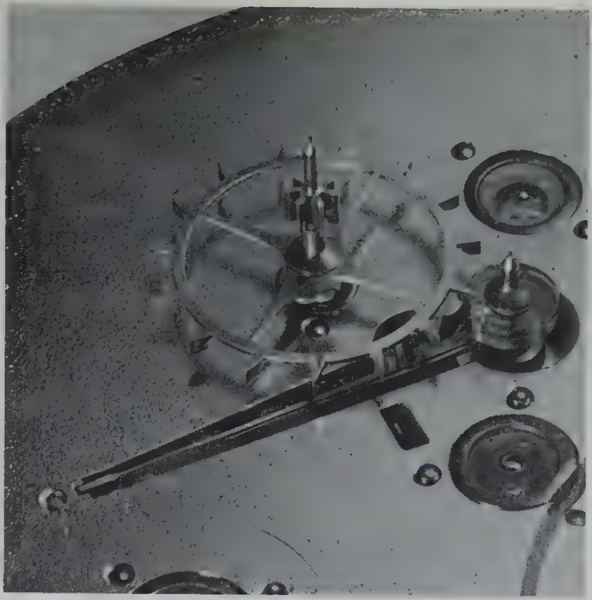

Perigal & Browne
Coventry Street
London
No 3020

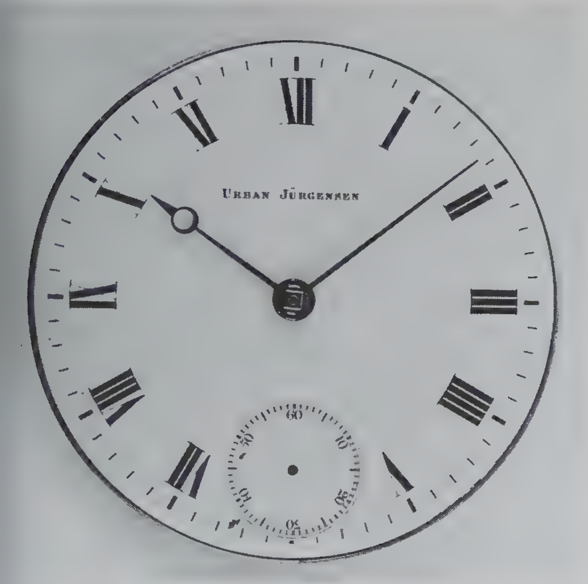
f

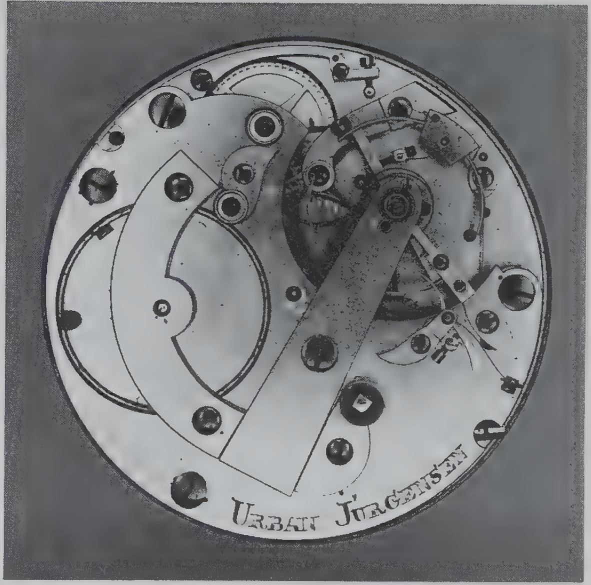
Plate 39

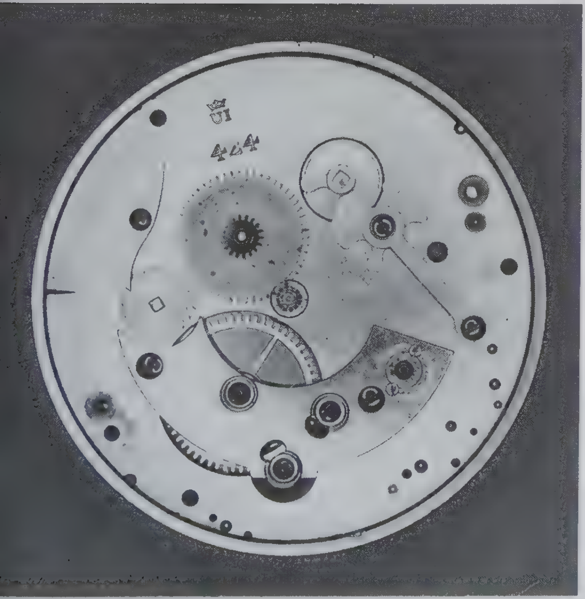
a. Cat. no. 55.
b. Cat. no. 56.
c. Cat. no. 56.
d. Cat. no. 56.
e. Cat. no. 56.
f. Cat. no. 56.


a


b


URBAN JÜRGENSEN
60
10
20
30
40
50
c


URBAN JÜRGENSEN
d



e

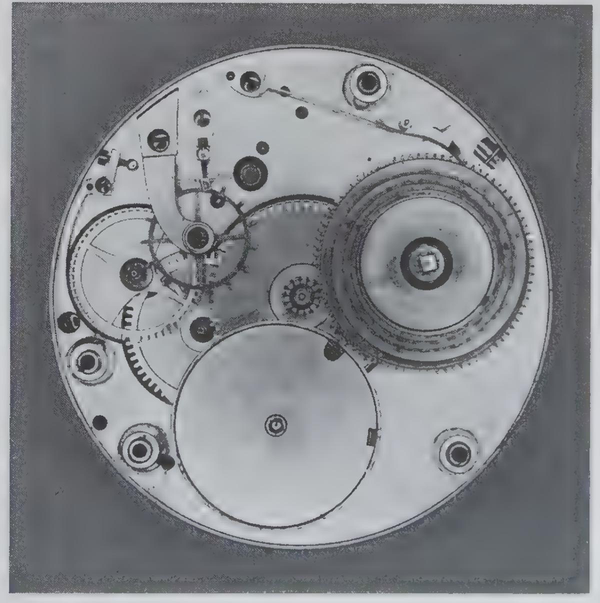
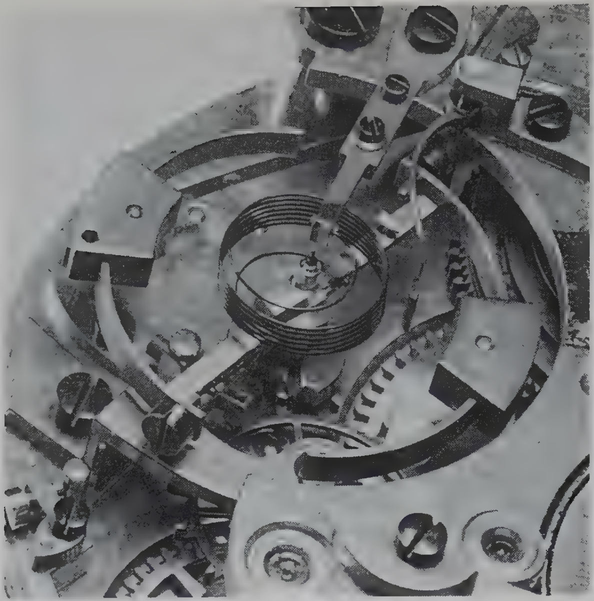
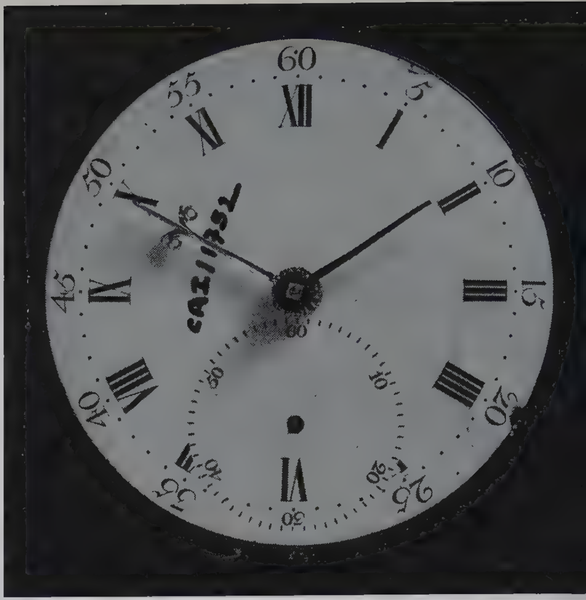
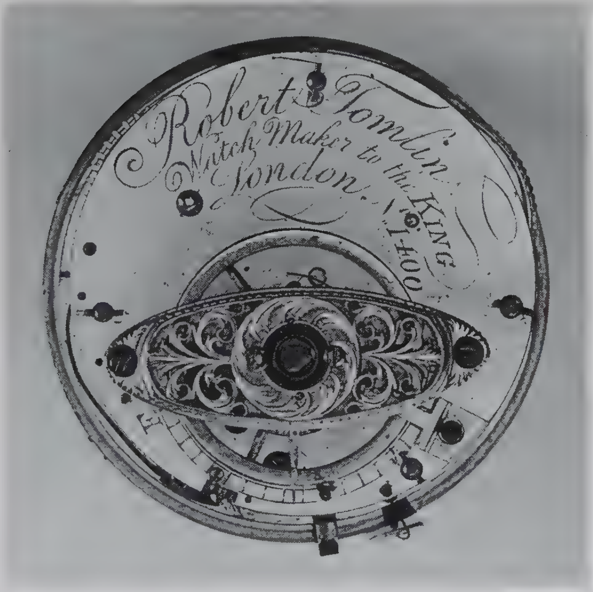

f

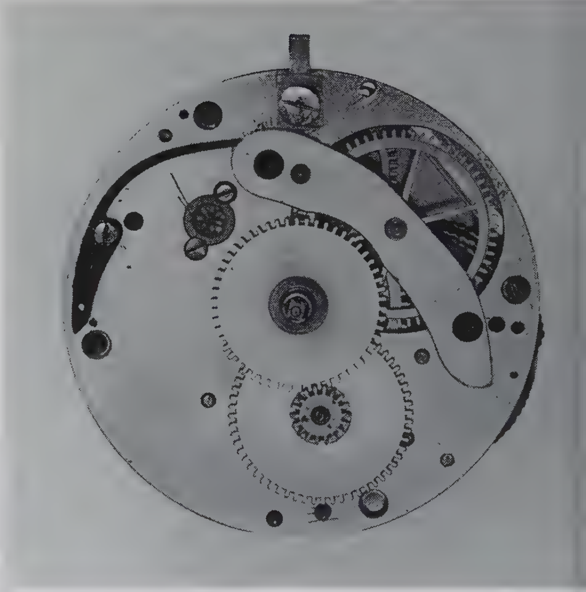
Plate 40

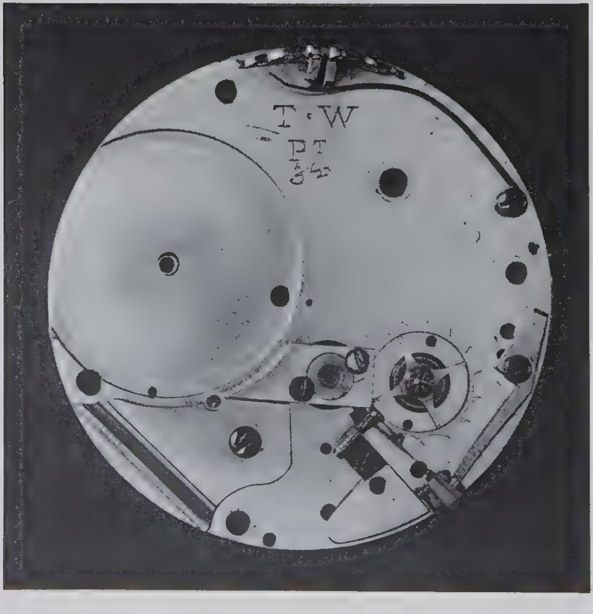
a. Cat. no. 56.
b. Cat. no. 57.
c. Cat. no. 57.
d. Cat. no. 57.
e. Cat. no. 57.
f. Cat. no. 57.
Note the worm set-up.


a


60
55
50
45
40
35
5
10
15
20
25
CA11952
60
10
20
30
40
50
b


Robert Tomlin
Watch Maker to the KING
London No 1400
c


d



e

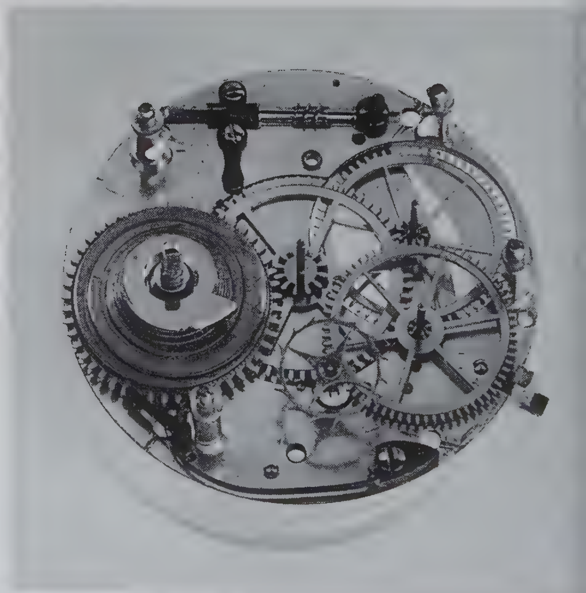
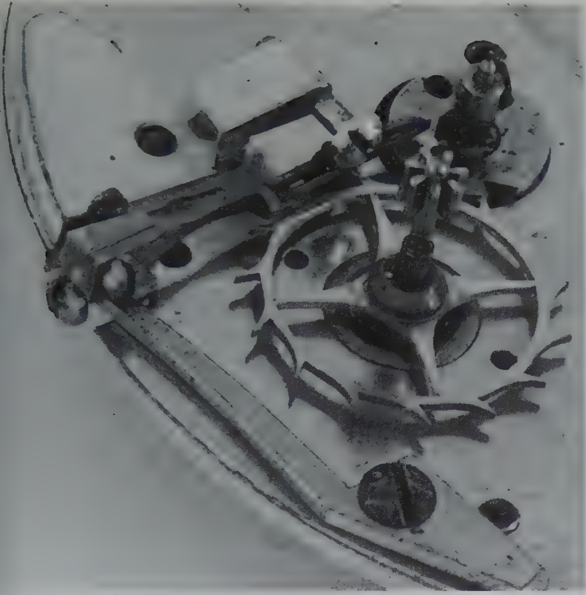
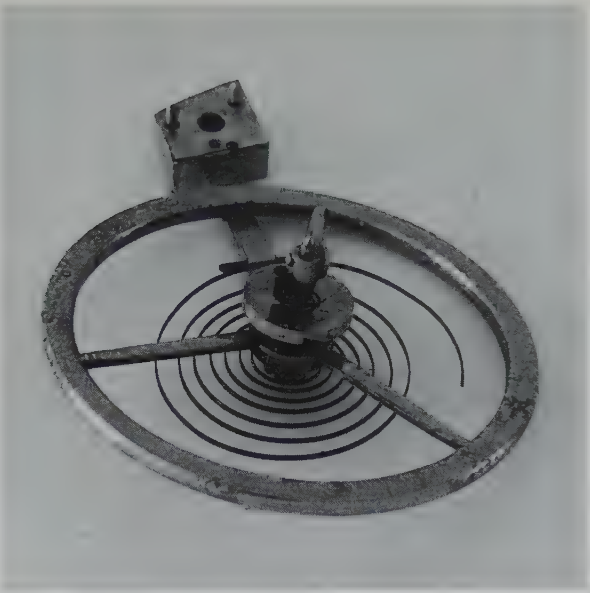
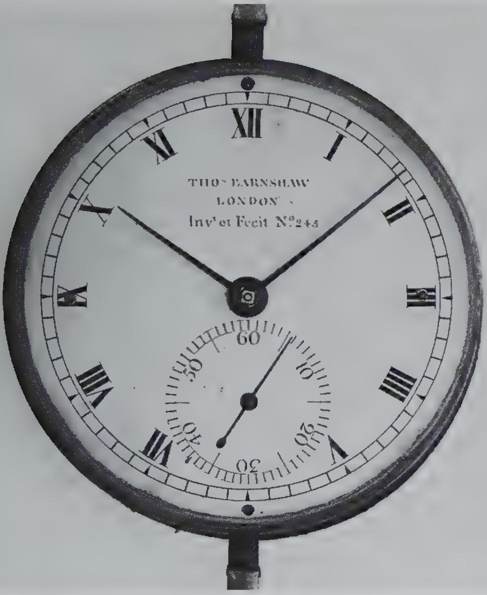

f

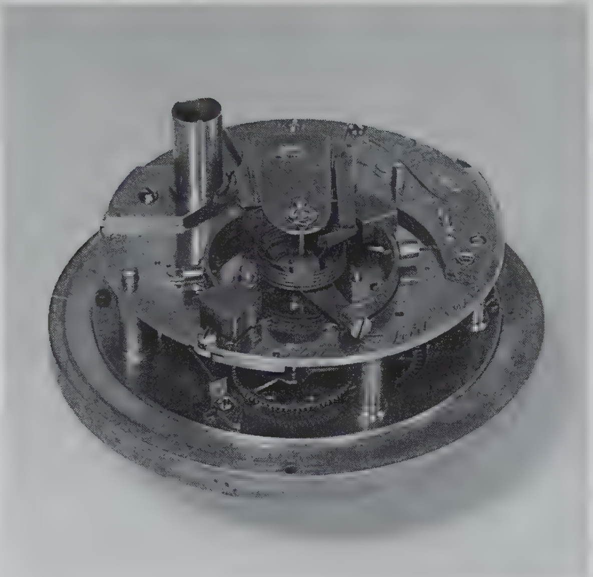
Plate 41

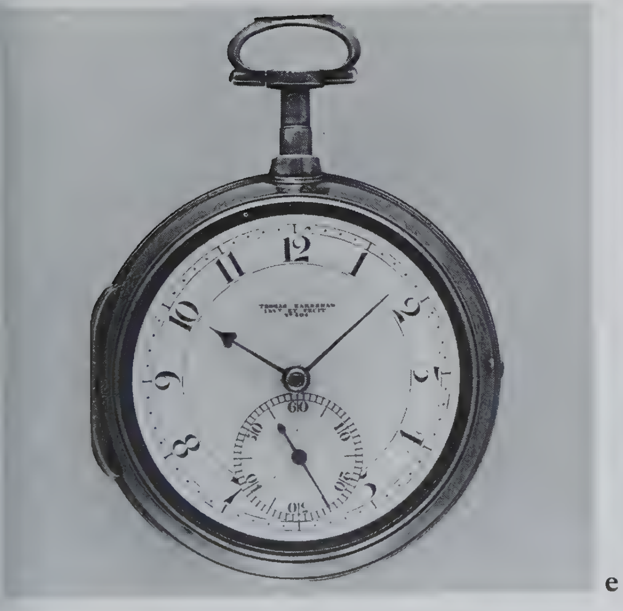
a. Cat. no. 57.
b. Cat. no. 57.
c. Cat. no. 58.
d. Cat. no. 58.
e. Cat. no. 59.
f. Cat. no. 59.


a


b


THOS EARNSHAW
LONDON
Invt et Fecit Nº243
c


d


e

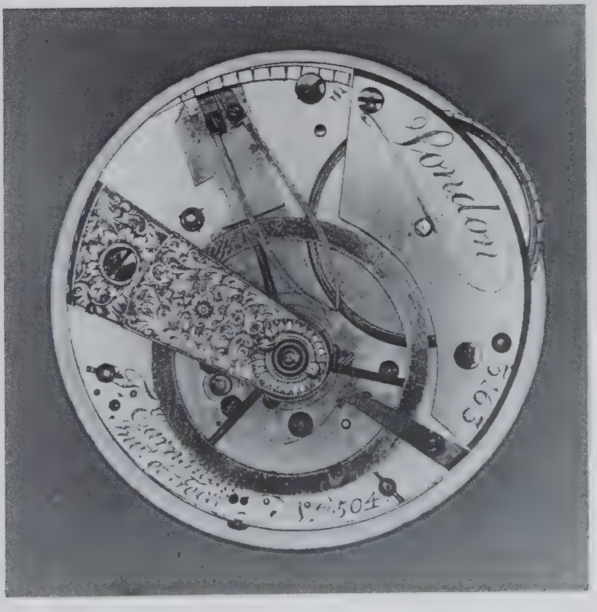
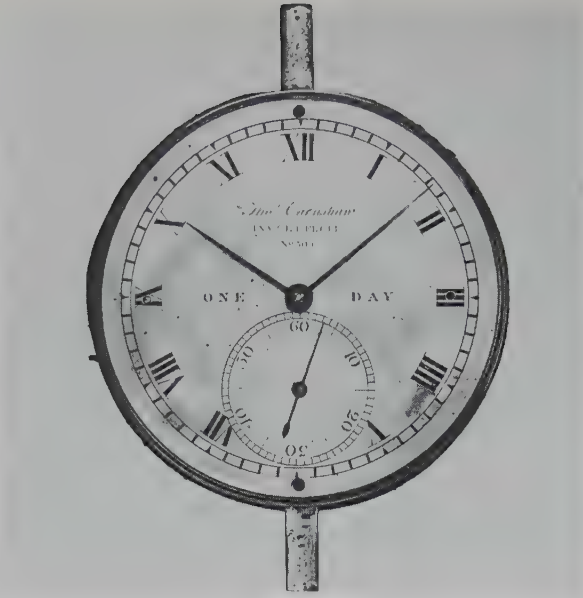
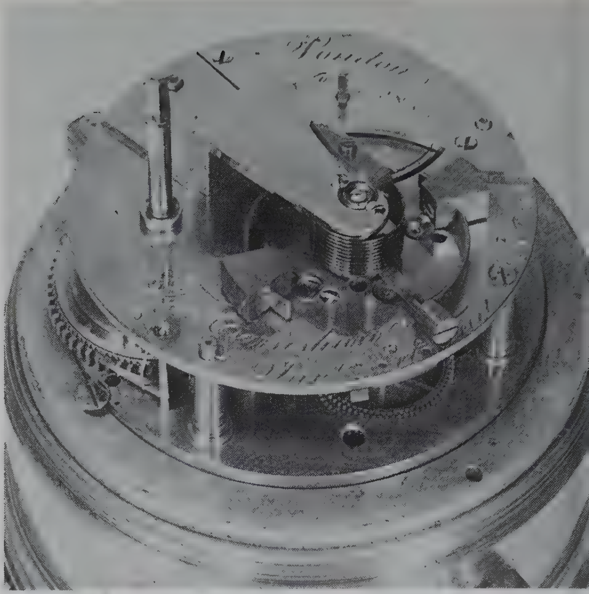

London
Nº 504
f

Plate 42

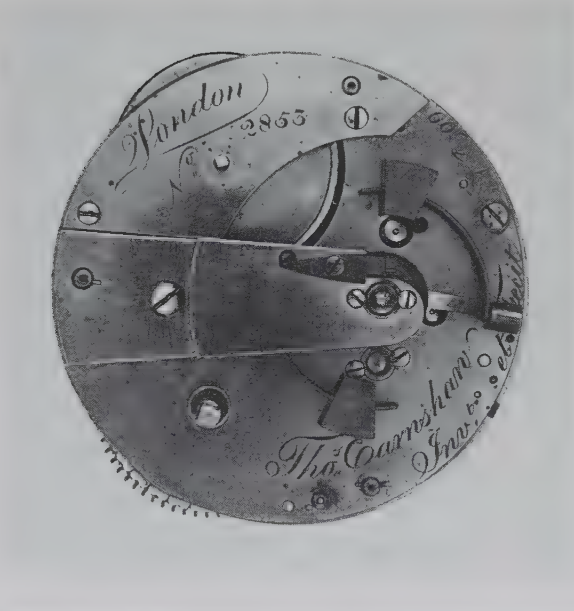
- **a.** Cat. no. 60.
- **b.** Cat. no. 60.
- **c.** Cat. no. 60.
- **d.** Cat. no. 60.
- **e.** Cat. no. 60.


ONE
DAY
60
10
20
30
40
50

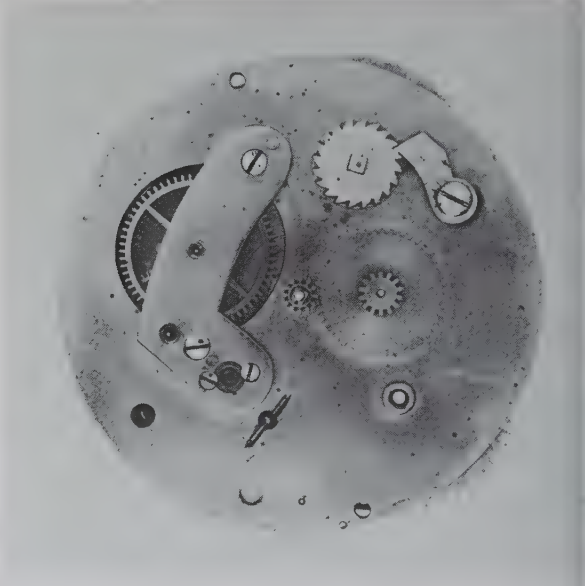
a



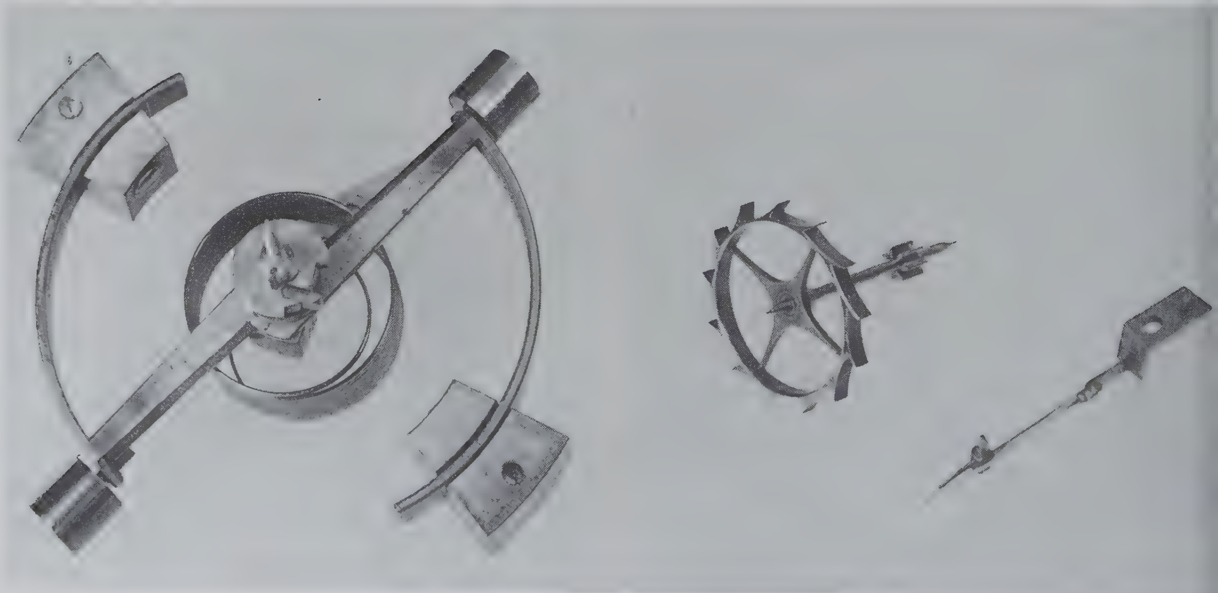
b


London
No. 2853
Thos. Earnshaw
Invt. et Fecit

c



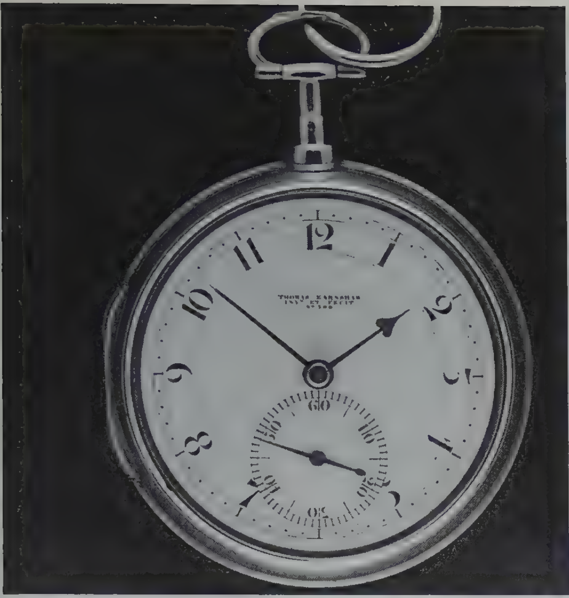
d

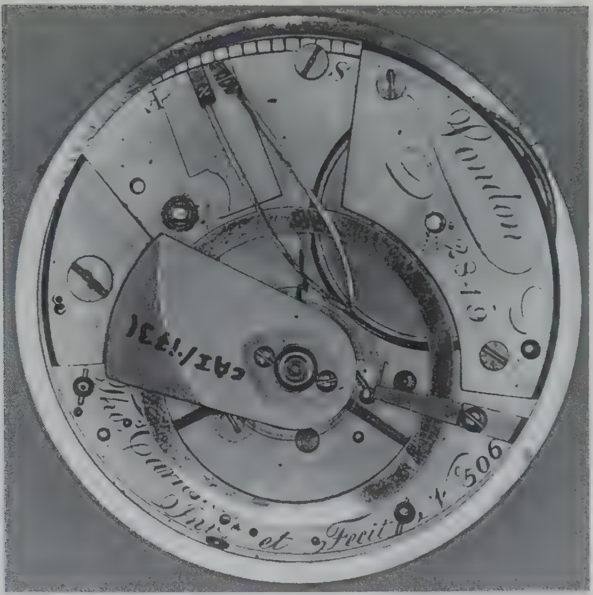


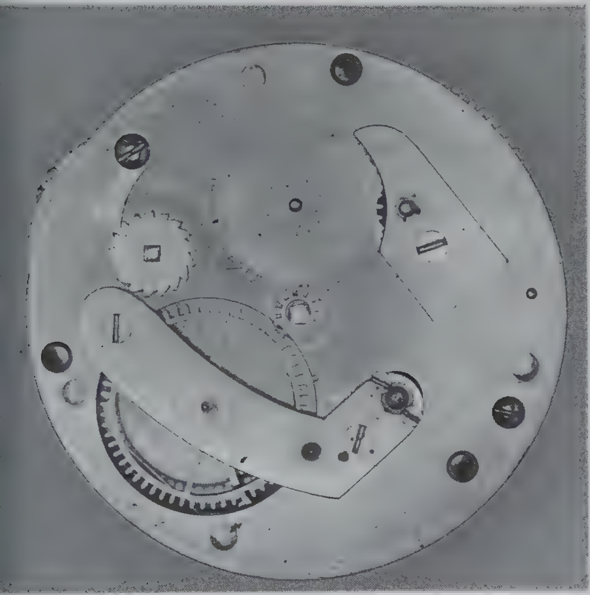
e

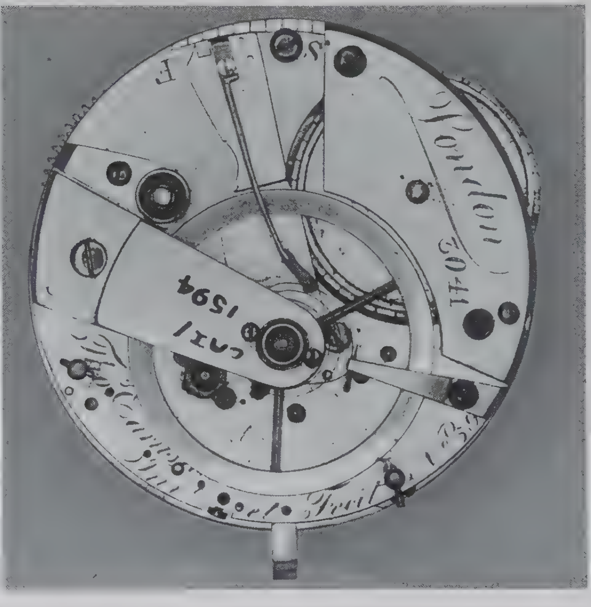
Plate 43

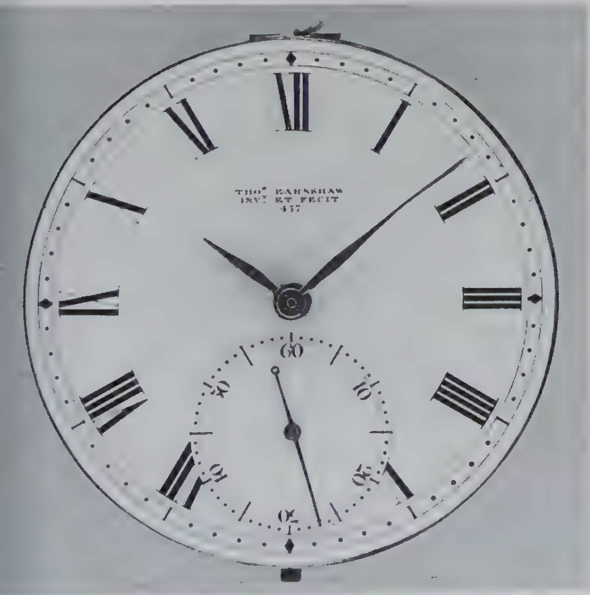
a. Cat. no. 61.
b. Cat. no. 61.
c. Cat. no. 61.
d. Cat. no. 62.
e. Cat. no. 63.
f. Cat. no. 63.


a


London
Thos Earnshaw Invt et Fecit No 506
b


c


London
1402
CAI/1594
Thos Earnshaw Invt et Fecit
d


THOs EARNSHAW
INVt ET FECIT
457
e

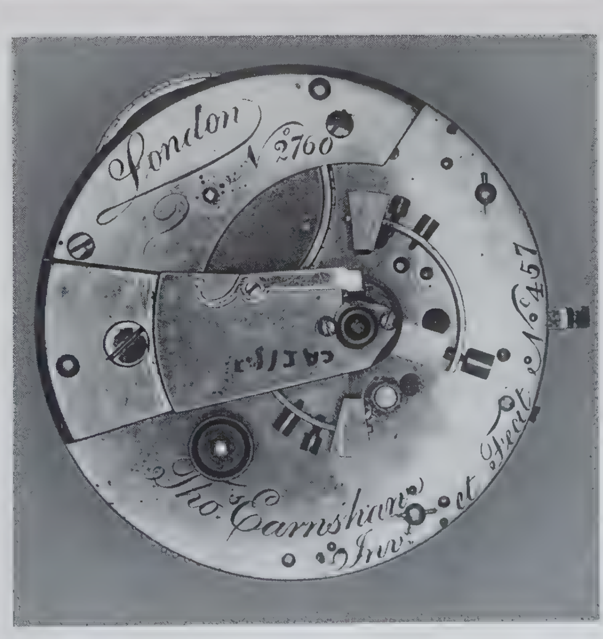
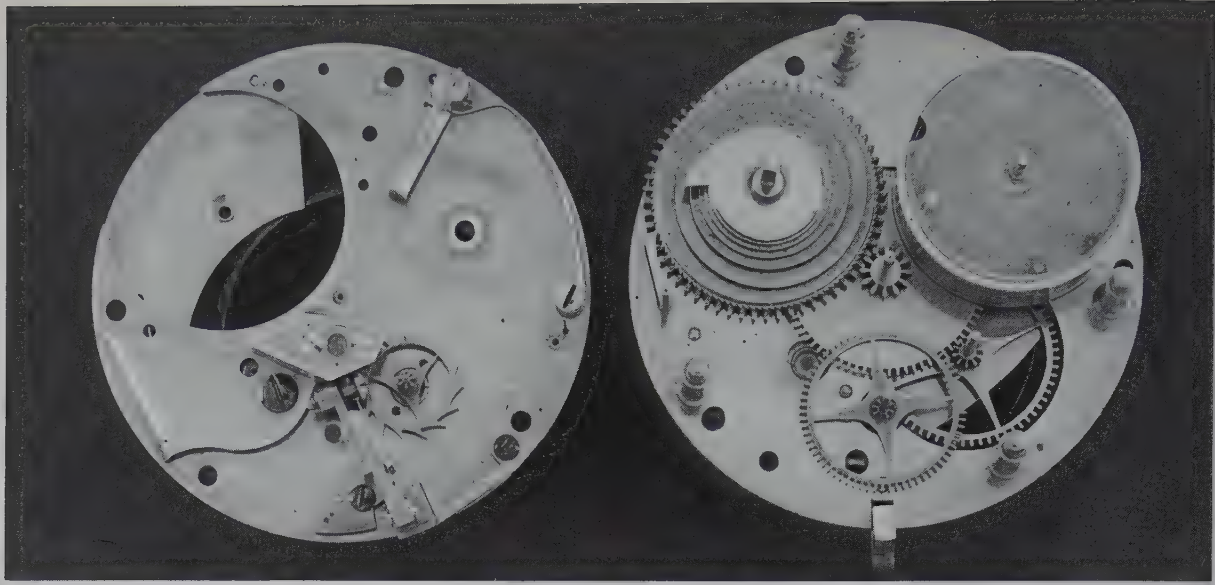
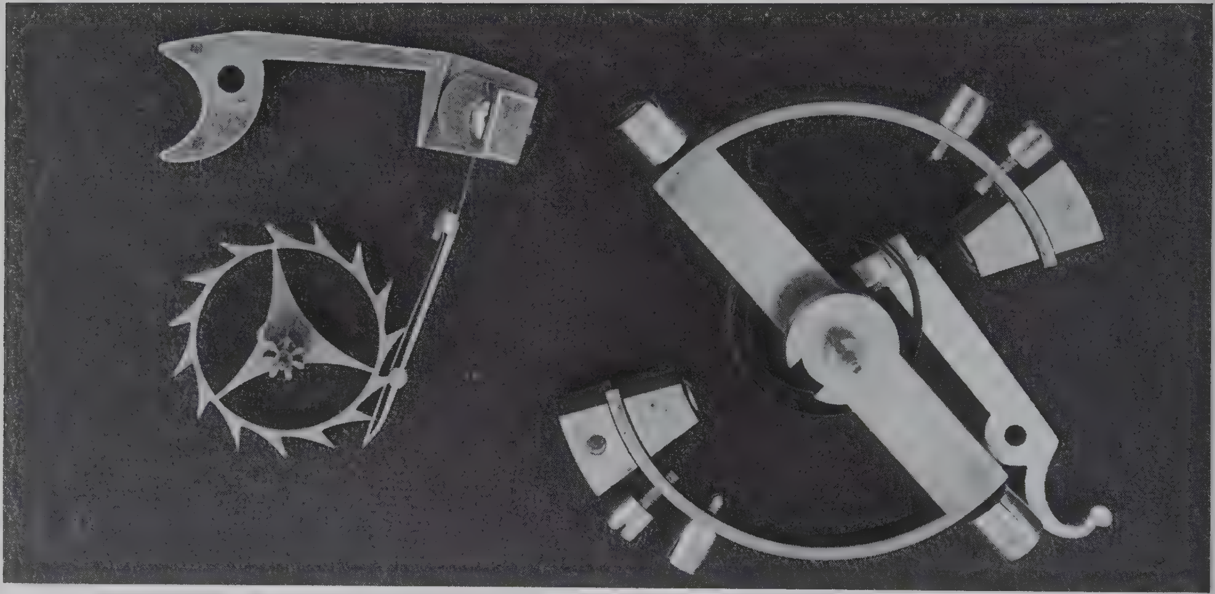

London
No 2760
Thos Earnshaw Invt et Fecit No 457
f

Plate 44

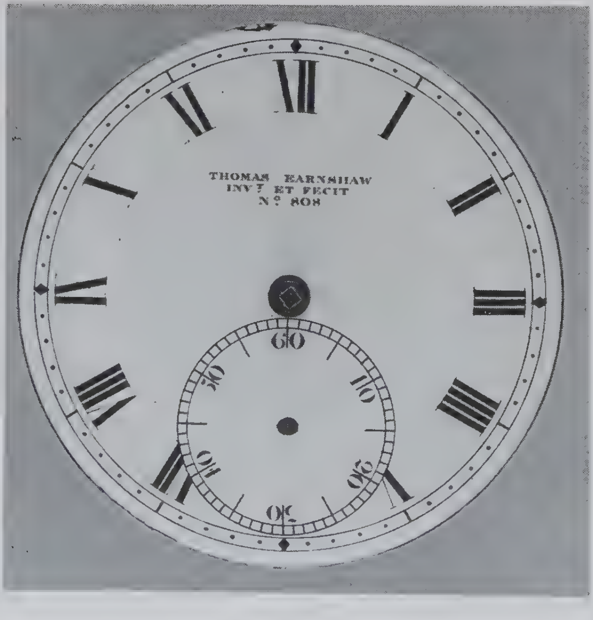
a. Cat. no. 63.
b. Cat. no. 63.
c. Cat. no. 64.
d. Cat. no. 64, balance and balance-cock missing.



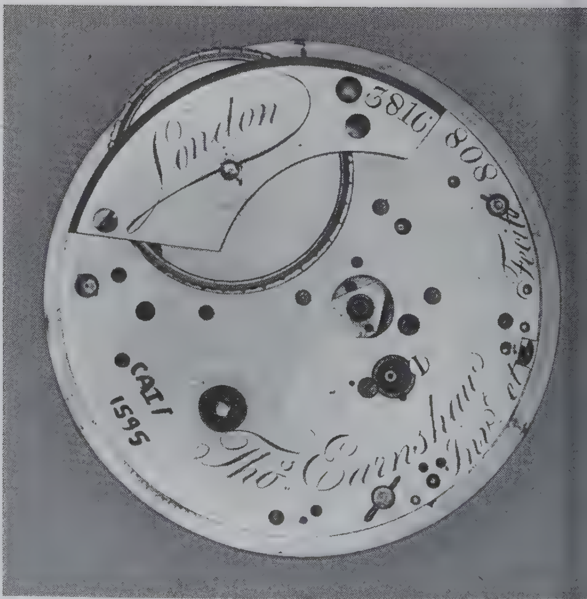
a



b


THOMAS EARNSHAW
INV^{T} ET FECIT
N° 808
60
10
20
30
40
50

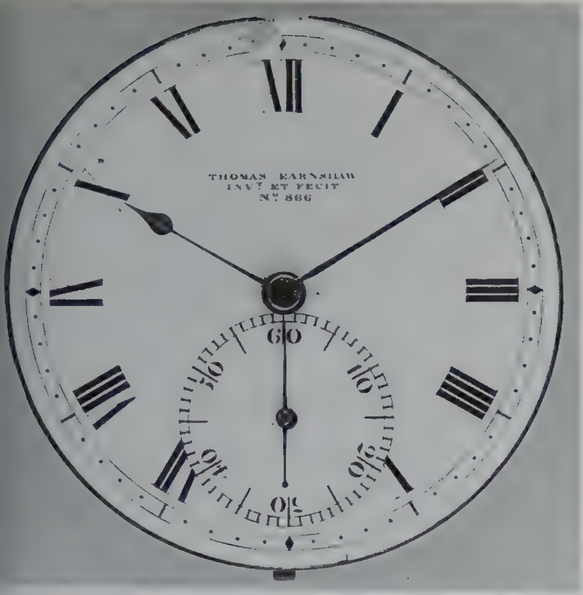
c


London
3816
808
Thos Earnshaw Invt et Fecit
CAT/
1595

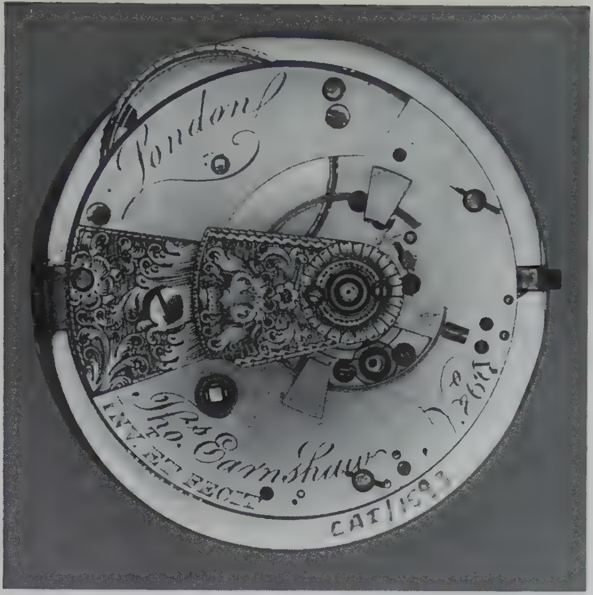
d

Plate 45

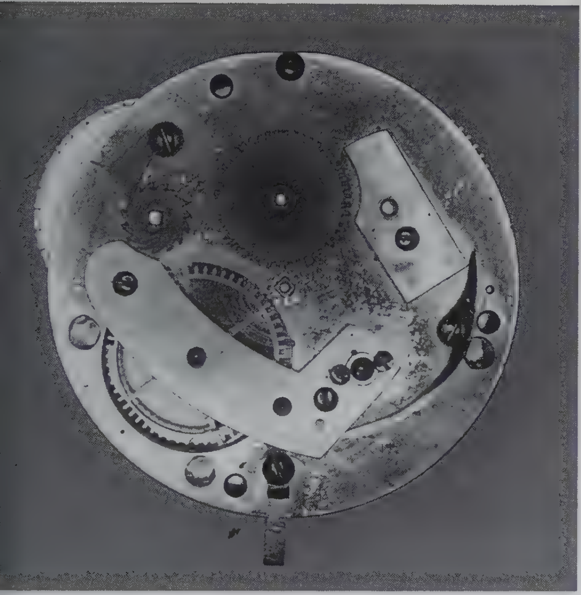
a. Cat. no. 65.
b. Cat. no. 65.
c. Cat. no. 65.
d. Cat. no. 65.
e. Cat. no. 66.
f. Cat. no. 66.


THOMAS EARNSHAW
INVT ET FECIT
No 866

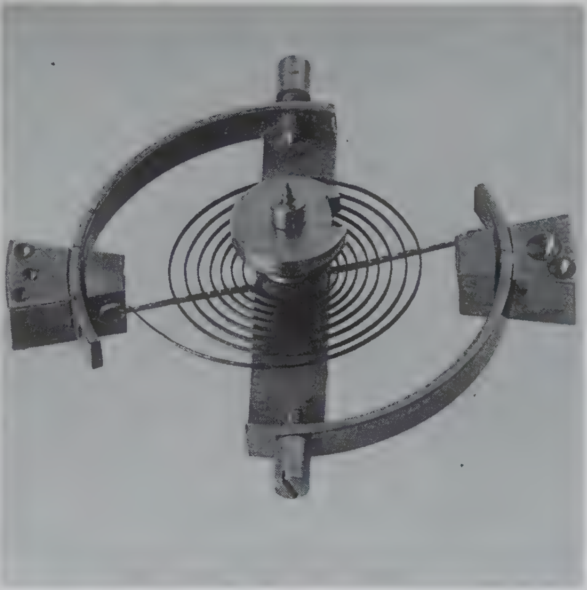
a


London
Thos Earnshaw
INVT ET FECIT

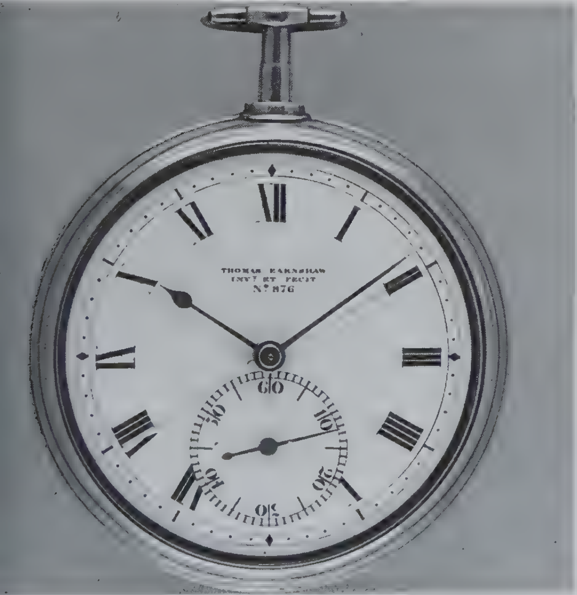
b



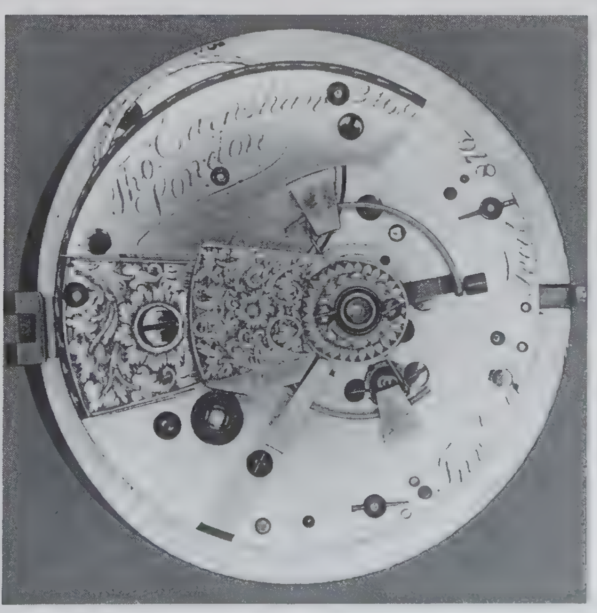
c



d


THOMAS EARNSHAW
INVT ET FECIT
No 876

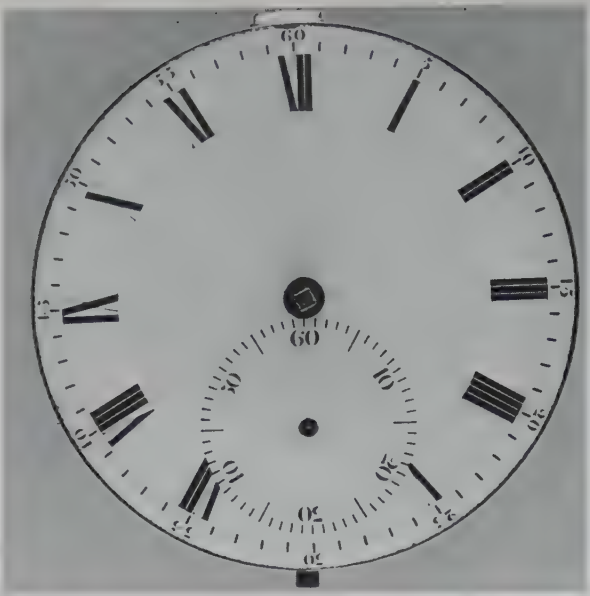
e


Tho. Earnshaw
London

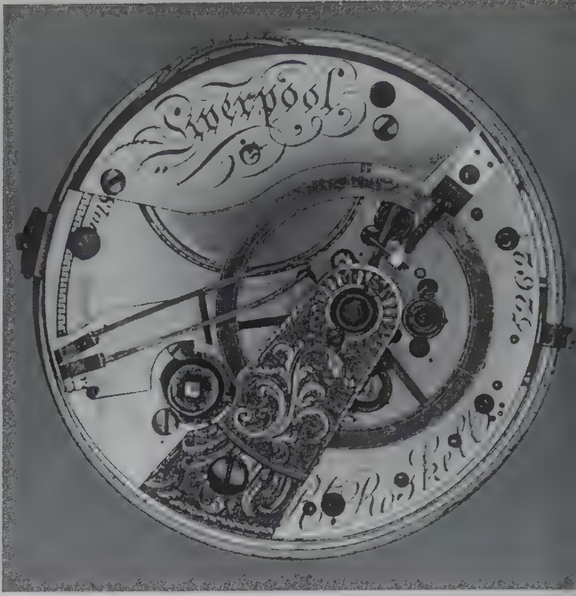
f

Plate 46

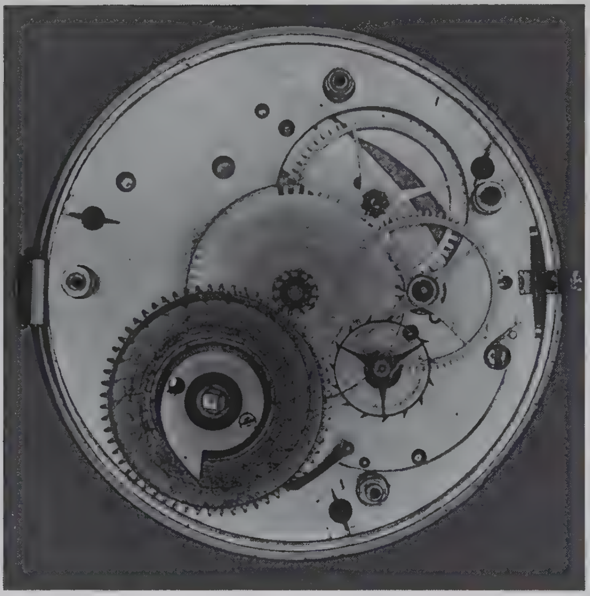
a. Cat. no. 67.
b. Cat. no. 67.
c. Cat. no. 67.
d. Cat. no. 67.
e. Cat. no. 68.
f. Cat. no. 68.



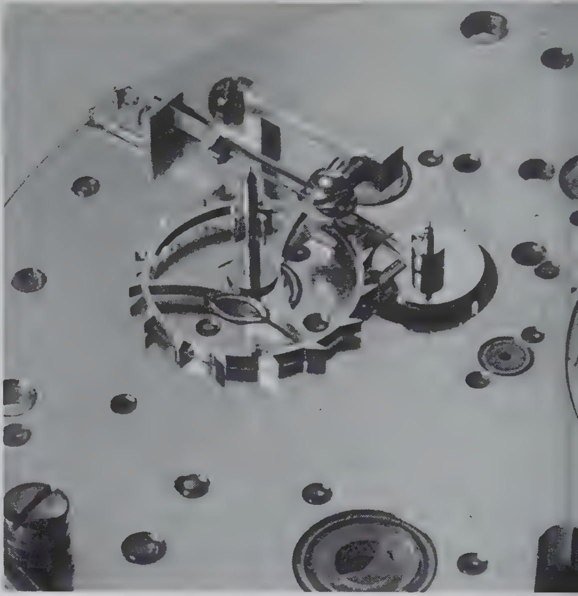
a



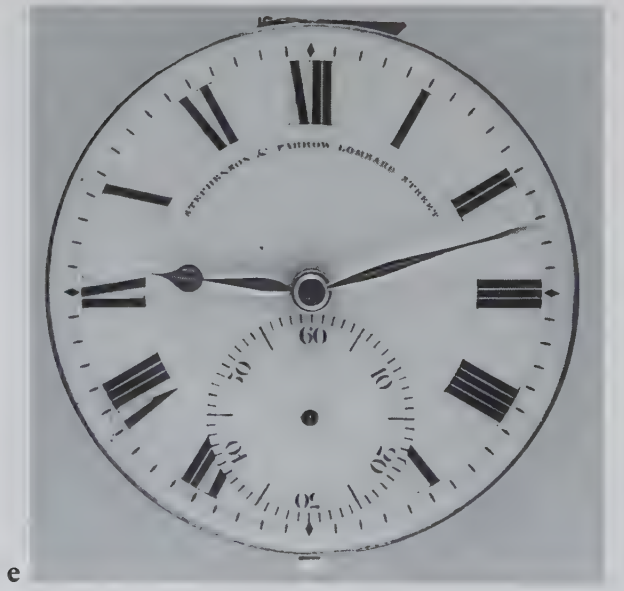
b



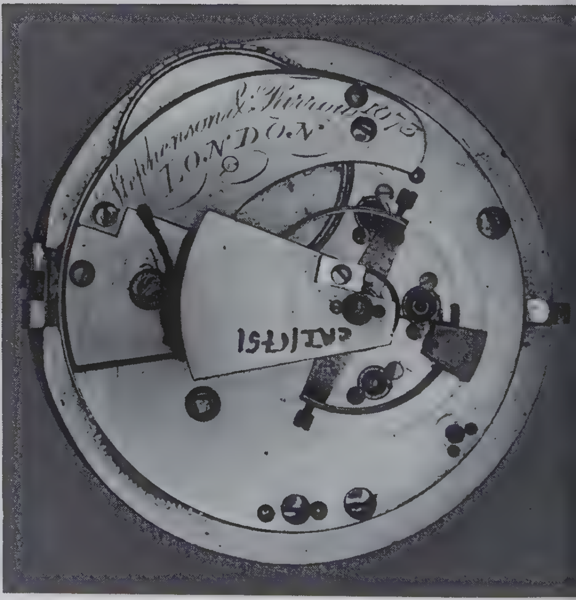
c



d


STEPHENSON & FARROW LOMBARD STREET

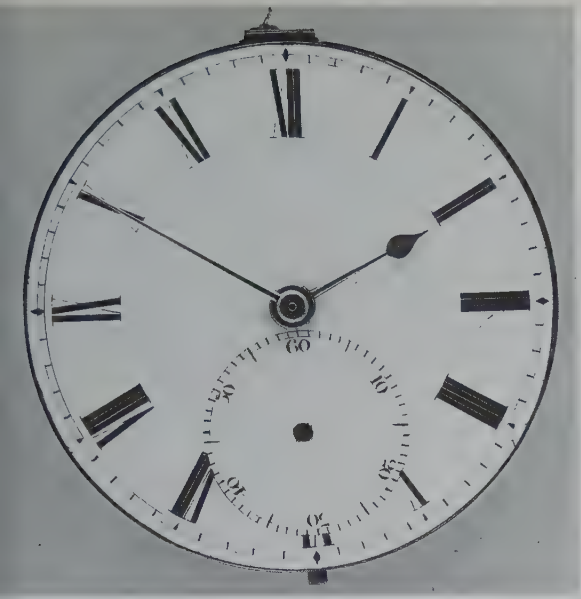
e


Stephenson & Farrow
LONDON

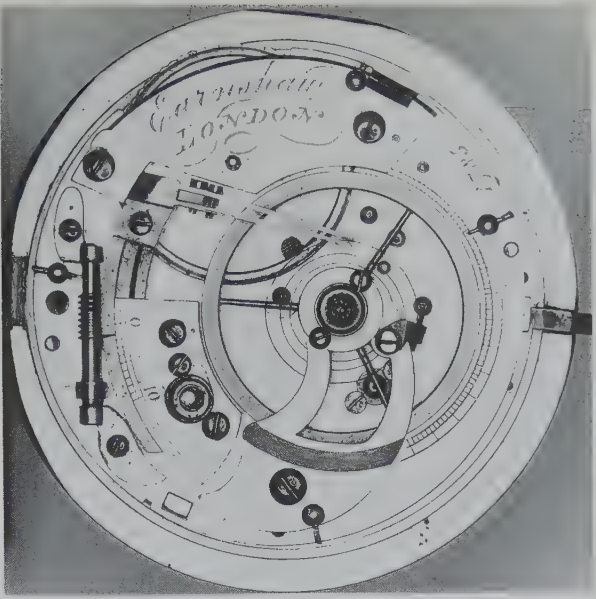
f

Plate 47

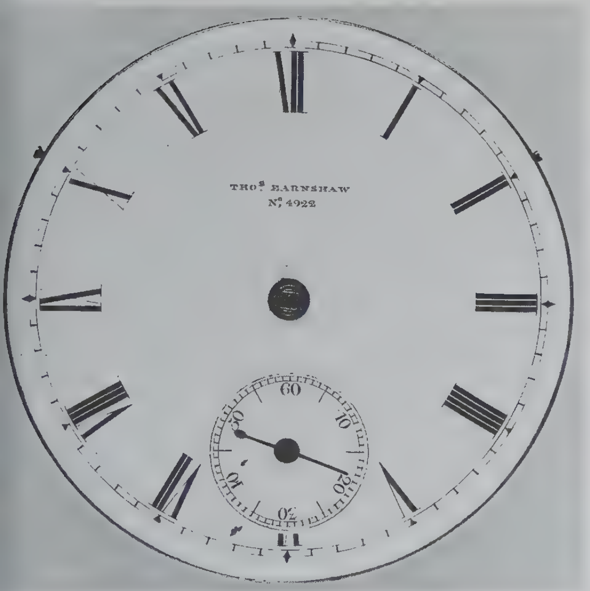
- **a.** Cat. no. 69.
- **b.** Cat. no. 69.
- **c.** Cat. no. 70.
- **d.** Cat. no. 70.
- **e.** Cat. no. 71.
- **f.** Cat. no. 71.



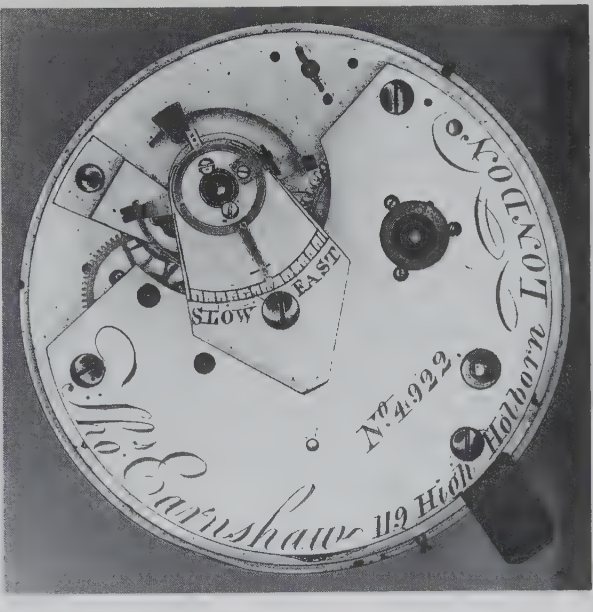
a


Earnshaw
LONDON

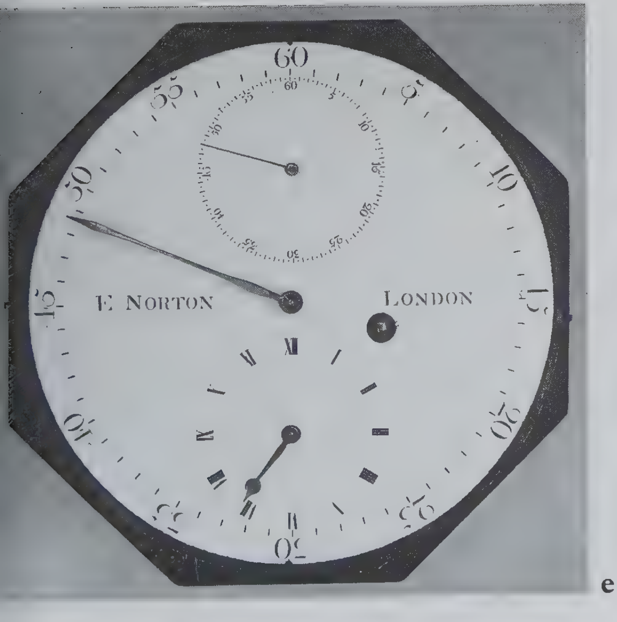
b


THOS EARNSHAW
No 4922

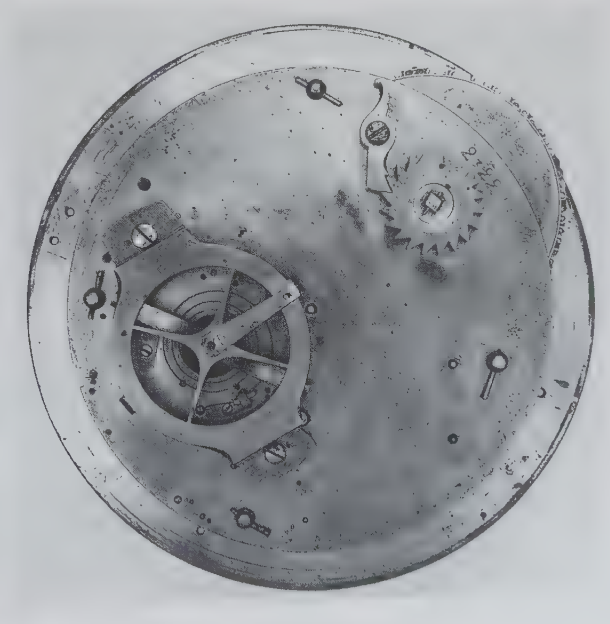
c


SLOW
FAST
LONDON
No 4922
Thos Earnshaw 119 High Holborn

d


E NORTON
LONDON

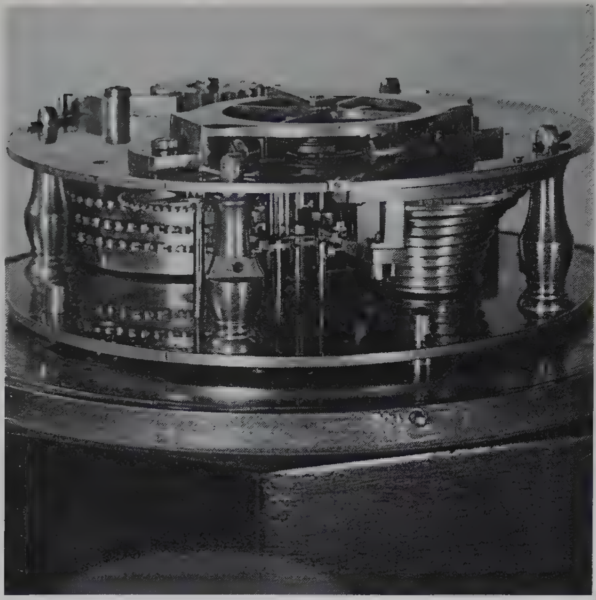
e

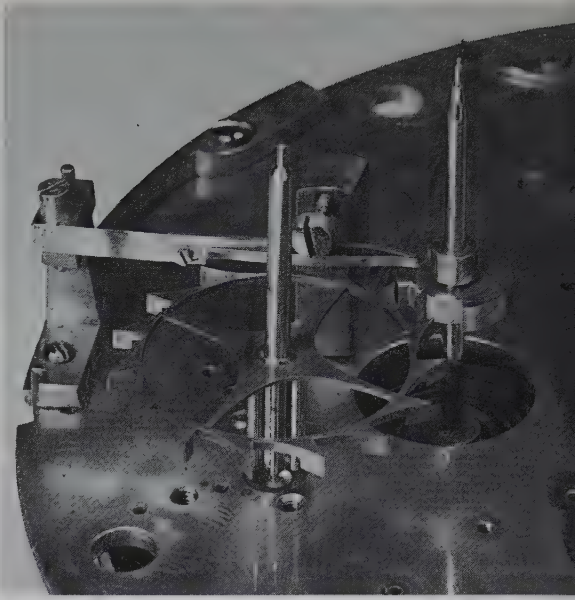


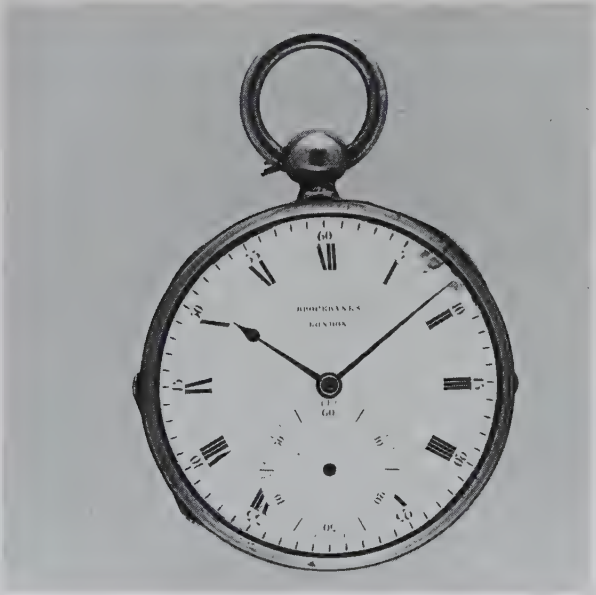
f

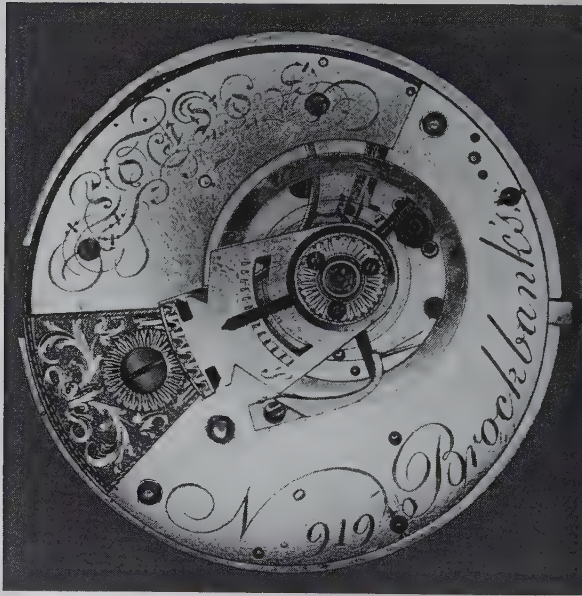
Plate 48

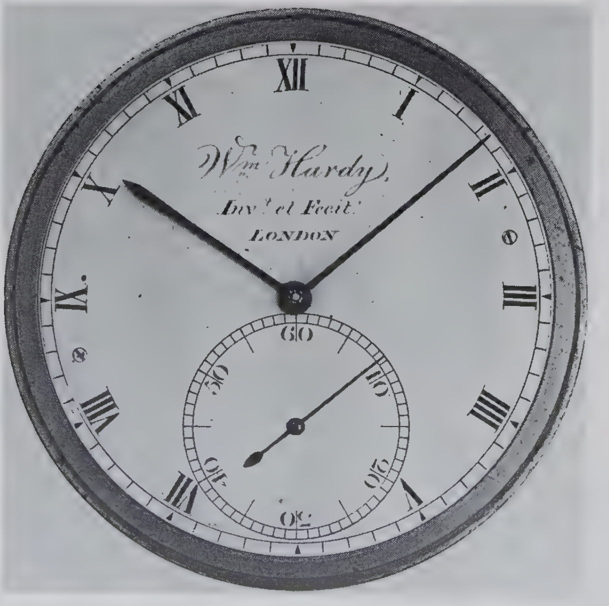
a. Cat. no. 71.
b. Cat. no. 71.
c. Cat. no. 72.
d. Cat. no. 72.
e. Cat. no. 73.
f. Cat. no. 73.


a


b


c
BROCKBANKS
LONDON


d
No 919 Brockbanks


e
Wm Hardy
Inv.t et Fecit.
LONDON

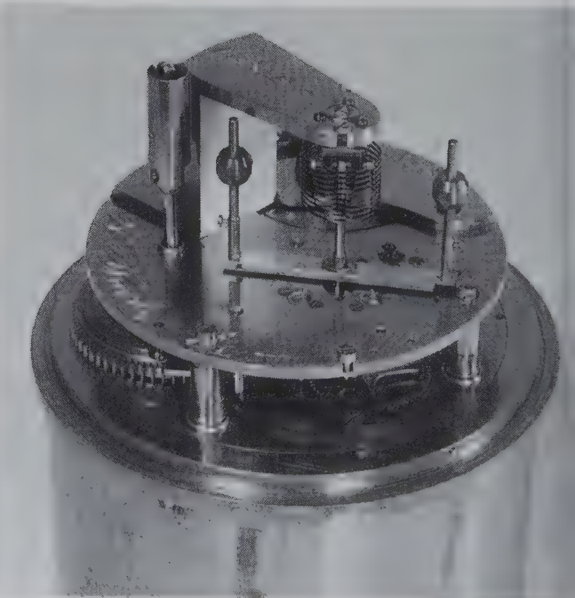
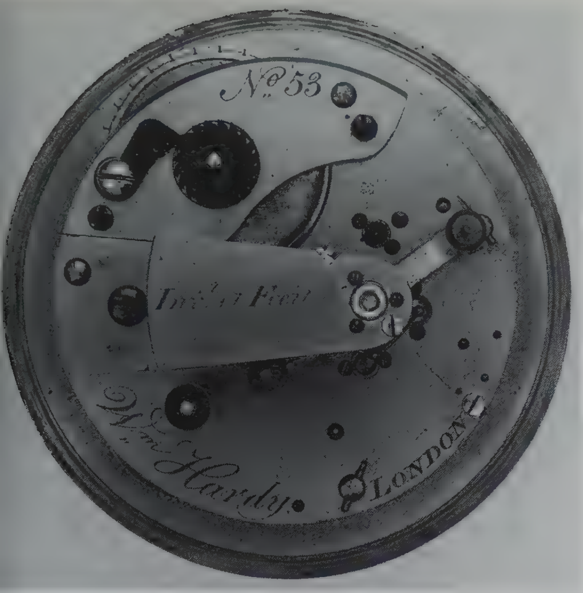
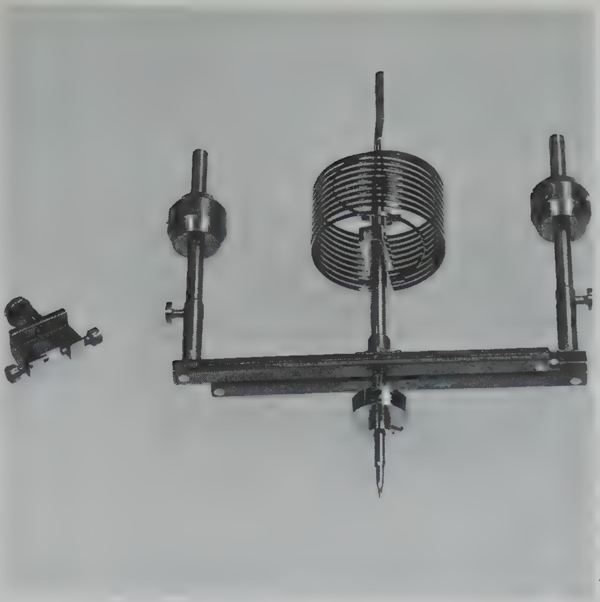

f

Plate 49

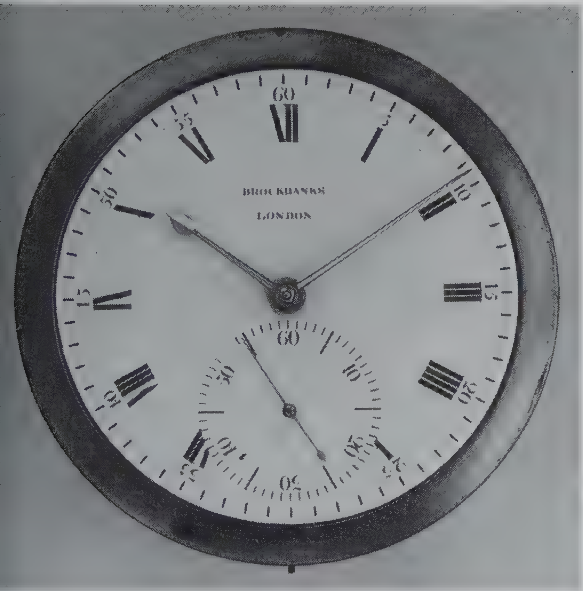
a. Cat. no. 73.
b. Cat. no. 73. The piece left of the illustration is the resilient stud banking device.
c. Cat. no. 74.
d. Cat. no. 74.
e. Cat. no. 74.


No. 53
Wm. Hardy
LONDON

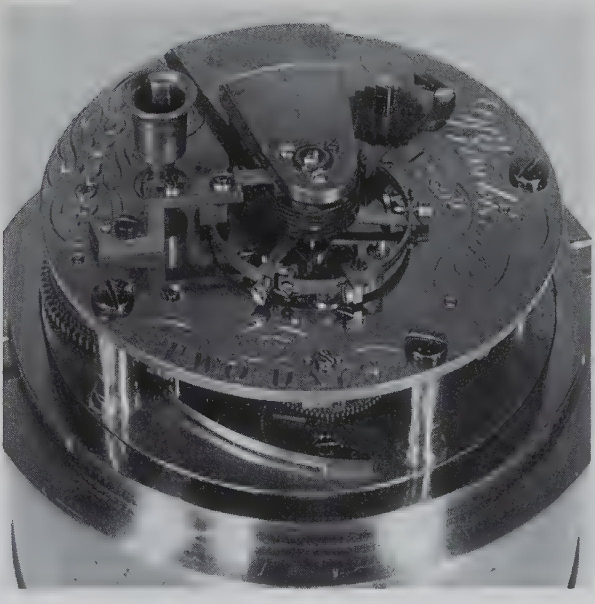
a



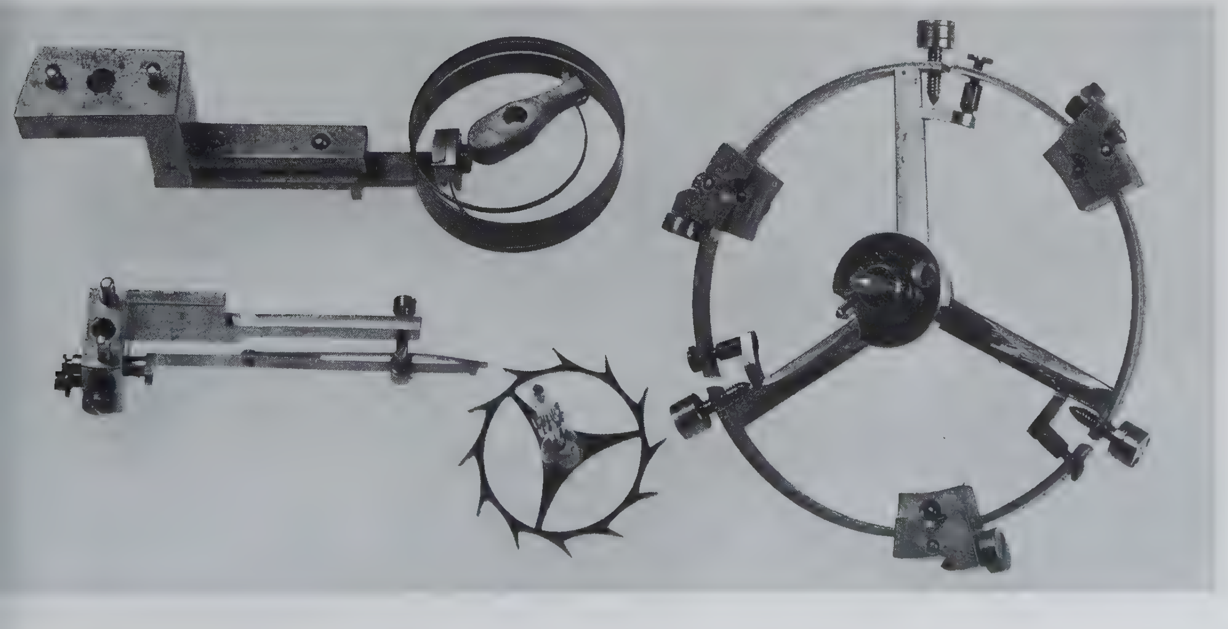
b


BROCKBANKS
LONDON

c



d



e

Plate 50

a. Cat. no. 75.
b. Cat. no. 75.
c. Cat. no. 75.
d. Cat. no. 75.
e. Cat. no. 76.
f. Cat. no. 76.

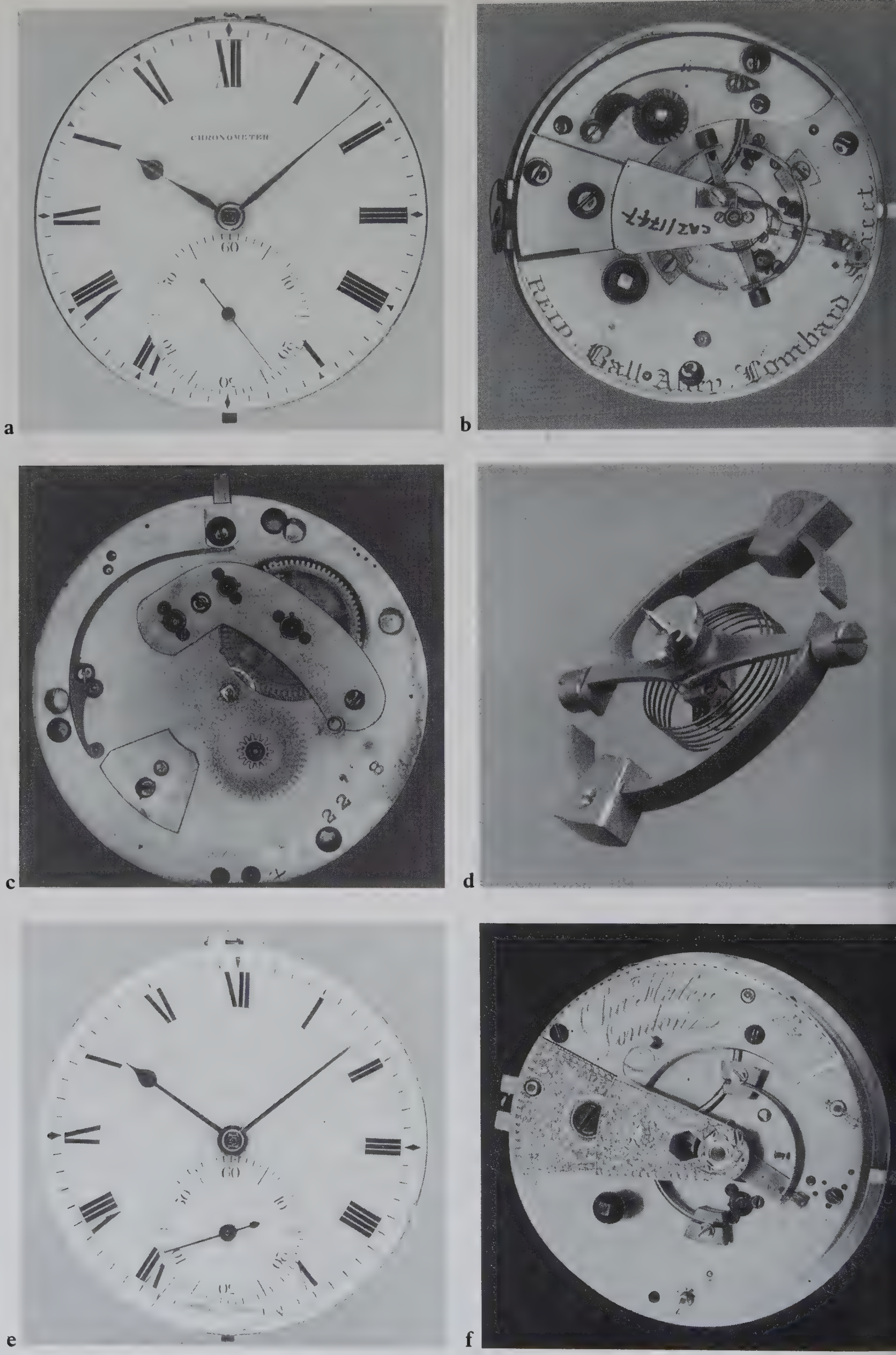
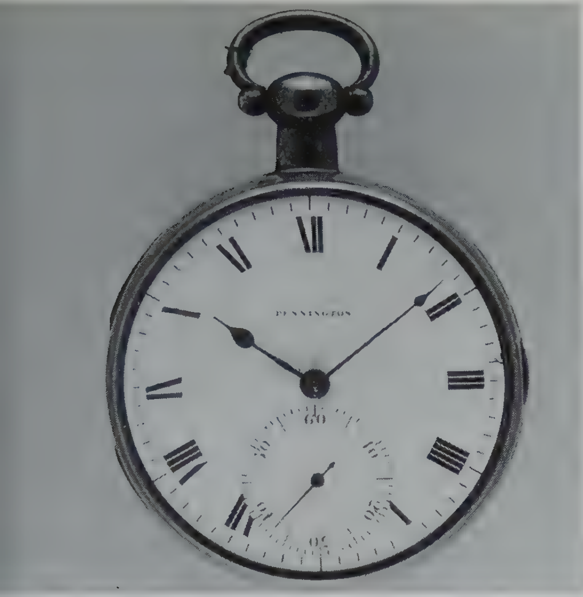
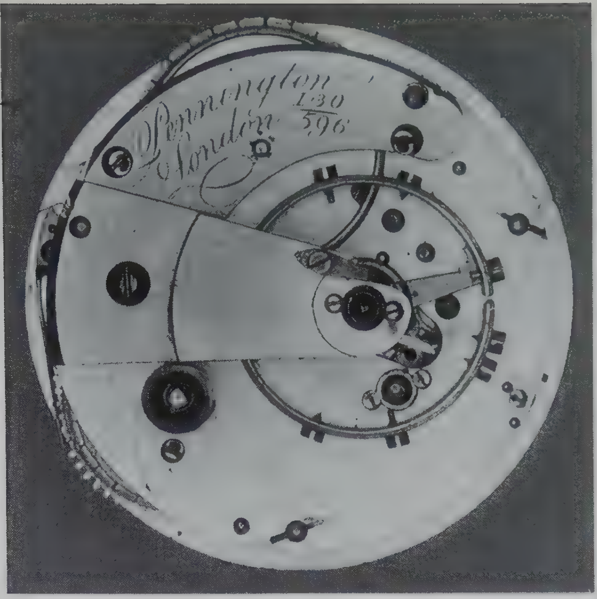

a
CHRONOMETER
60
b
CA2/1747
REID. Ball Alley. Lombard Street
c
221.8
d
e
60
f

Plate 51

a. Cat. no. 77.
b. Cat. no. 77.
c. Cat. no. 78.
d. Cat. no. 78.
e. Cat. no. 78.
f. Cat. no. 78.

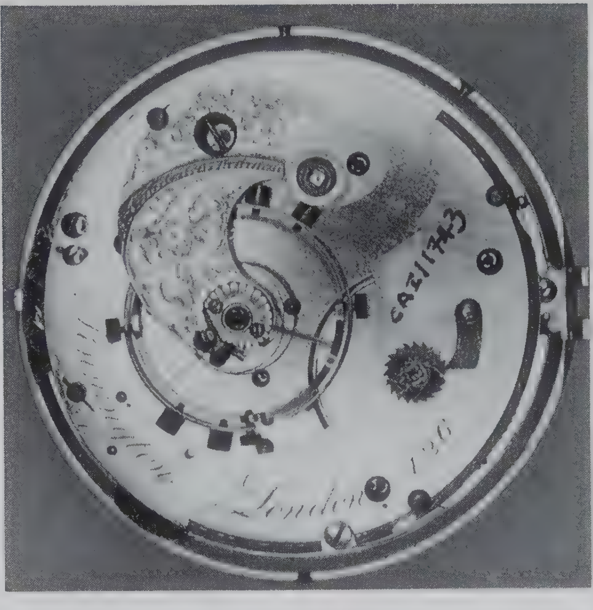

PENNINGTON

a

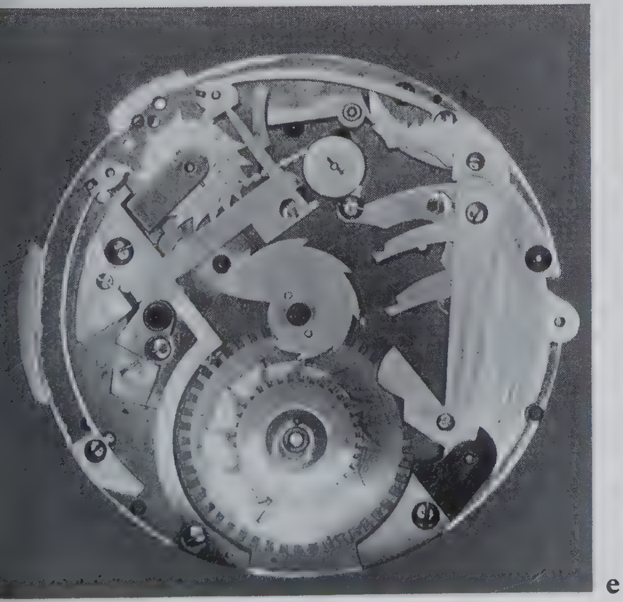

Pennington
London
130
596

b

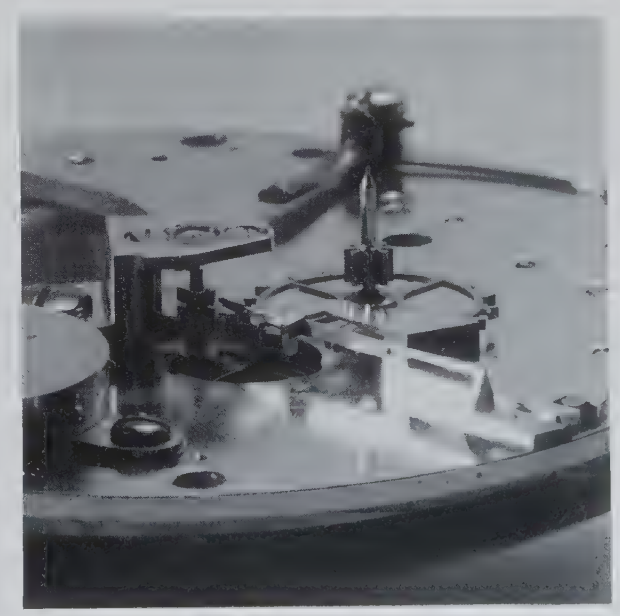
c


CA21743
London
136

d



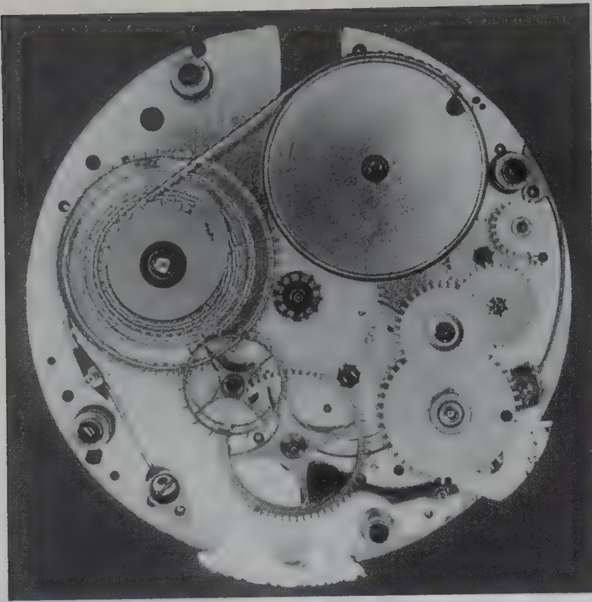
e



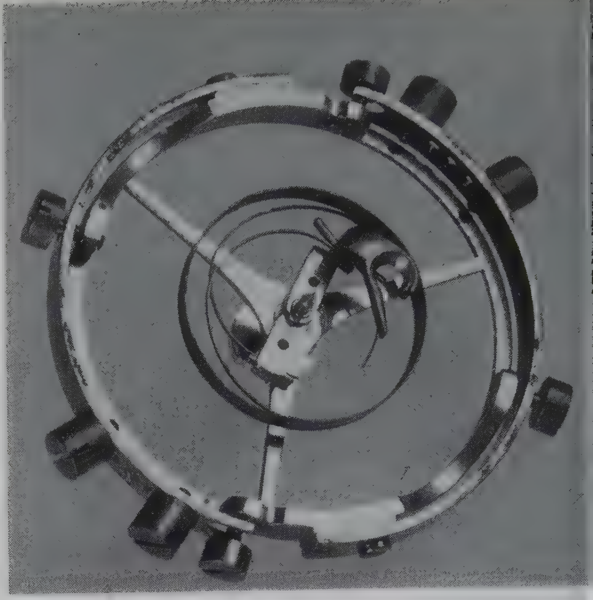
f

Plate 52

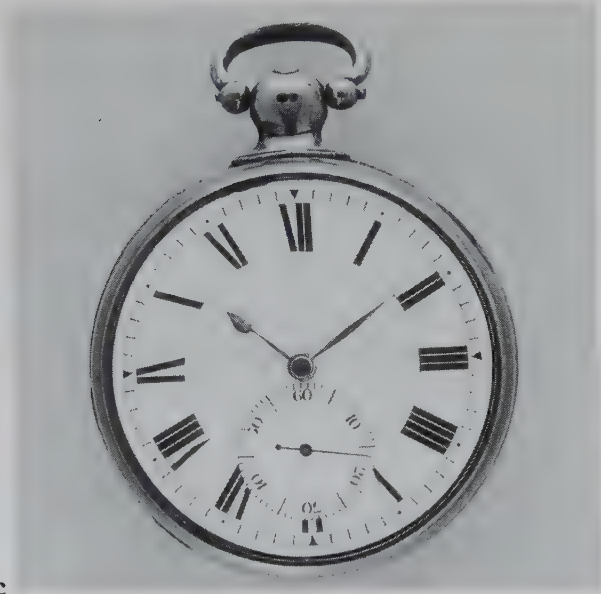
a. Cat. no. 78.
b. Cat. no. 78.
c. Cat. no. 79.
d. Cat. no. 79.
e. Cat. no. 80.
f. Cat. no. 80.



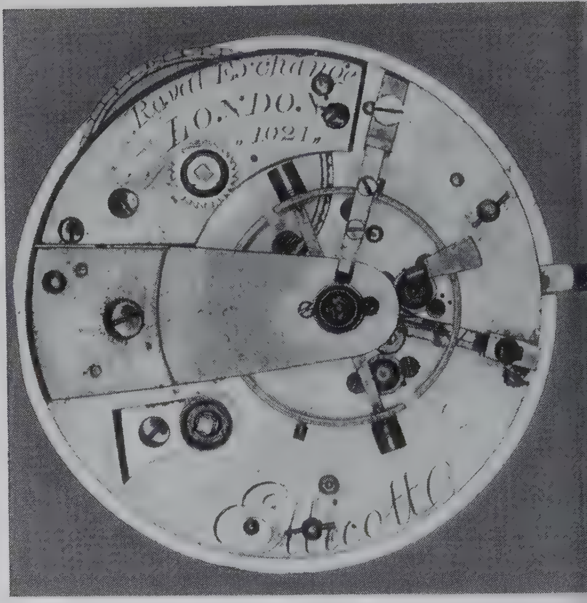
a



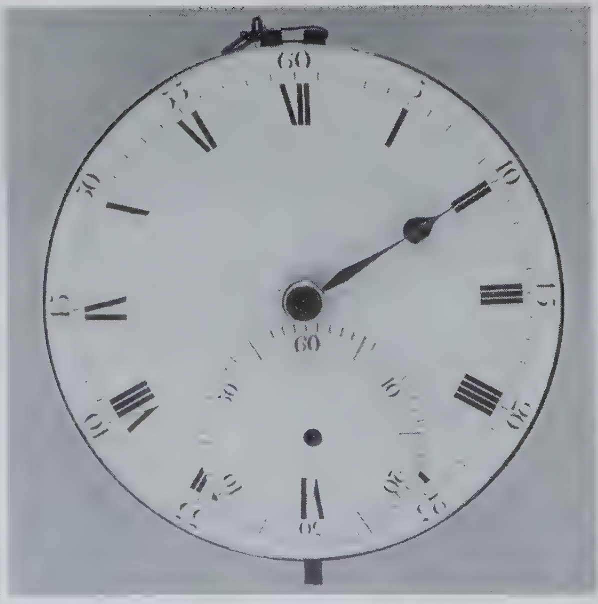
b



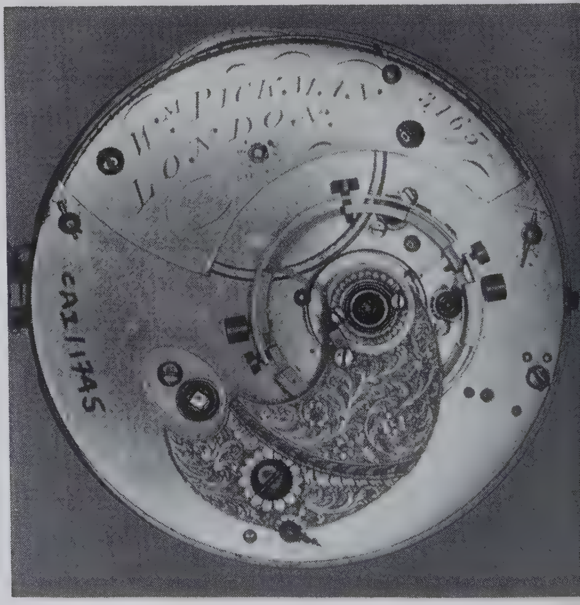
c


Royal Exchange
LONDON
1021
Ellicott

d



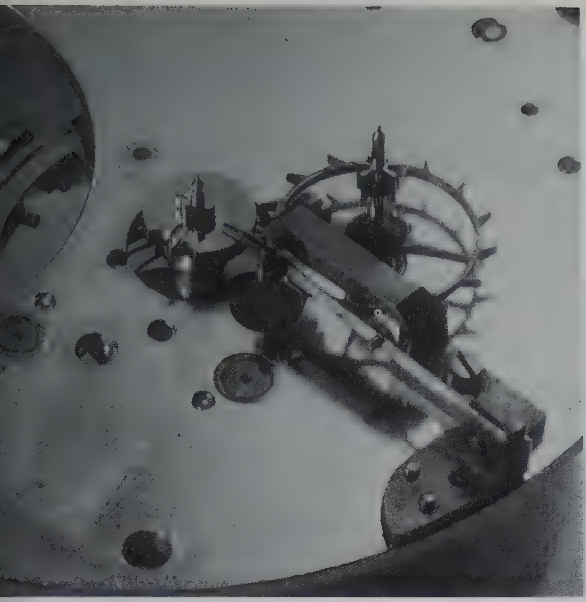
e

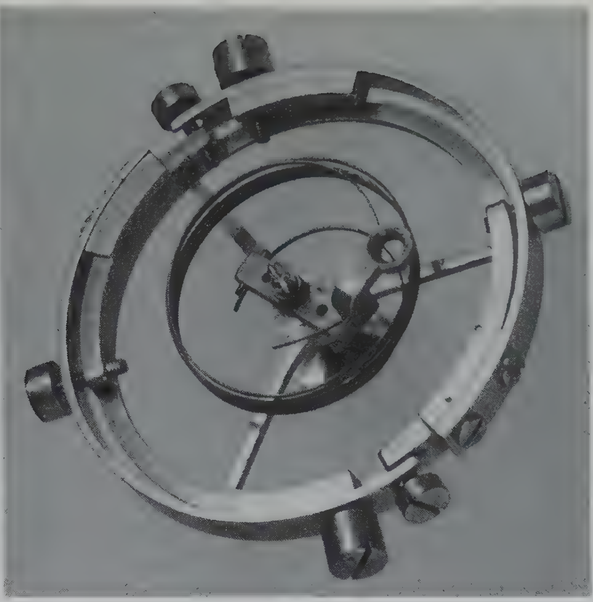

Wm PICKMAN 2165
LONDON
CA11745

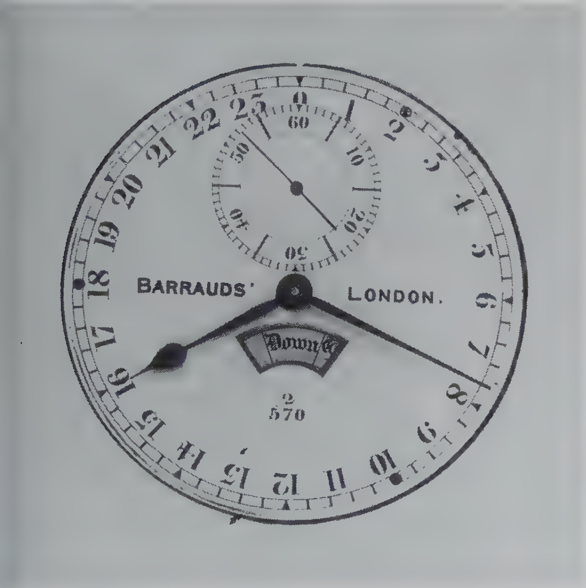
f

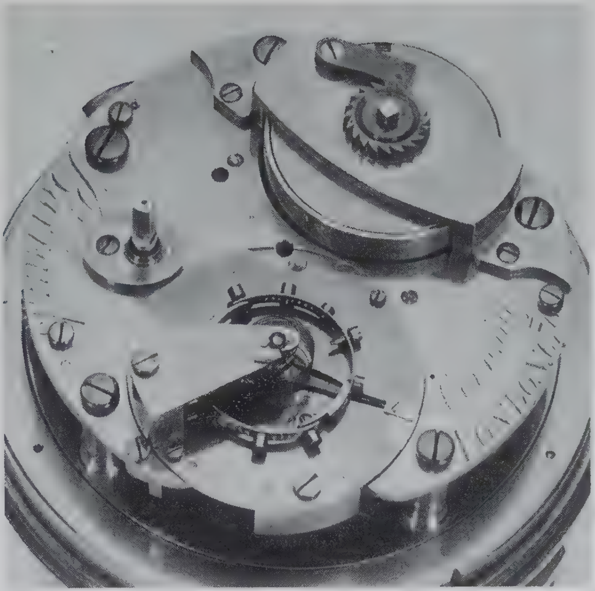
Plate 53

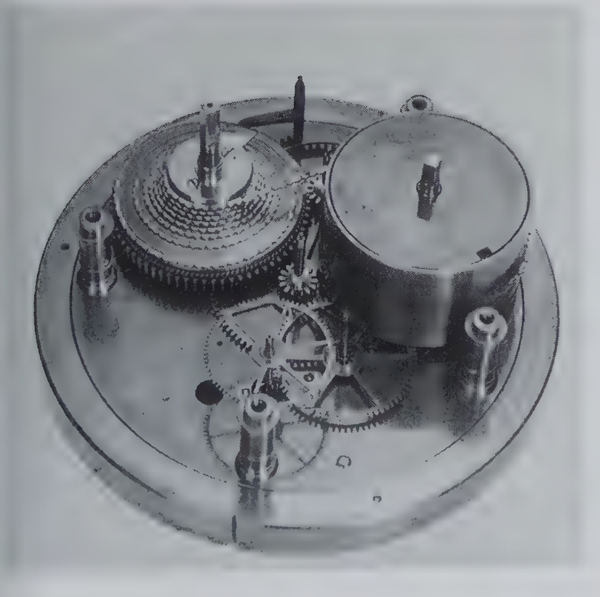
a. Cat. no. 80.
b. Cat. no. 80.
c. Cat. no. 81.
d. Cat. no. 81.
e. Cat. no. 81.
Note the reverse fusee.
f. Cat. no. 81.


a


b


BARRAUDS' LONDON.
Down
2
570
60
10
20
30
40
50
c


d


e

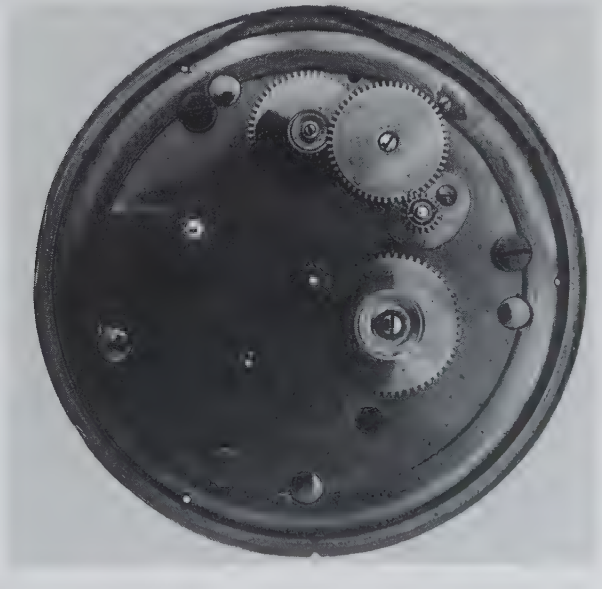
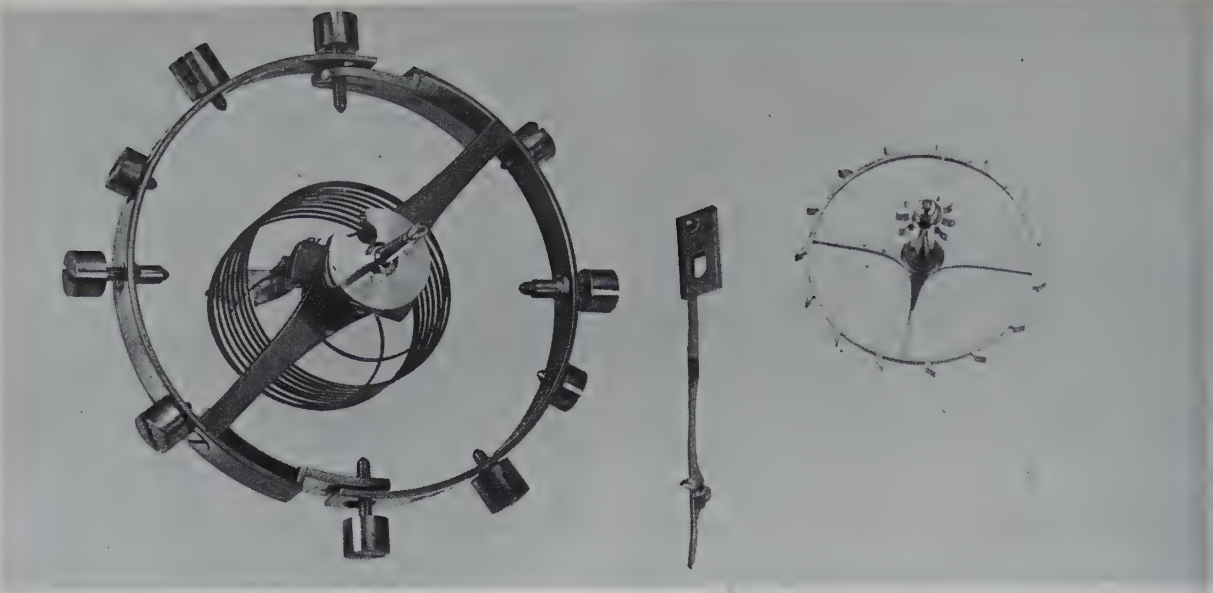
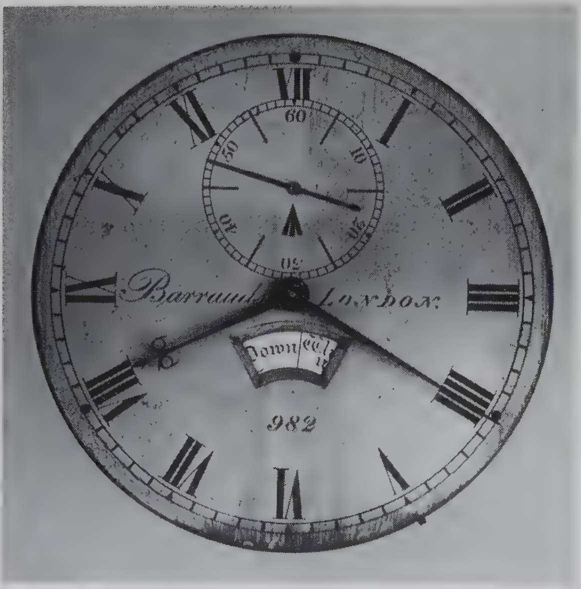
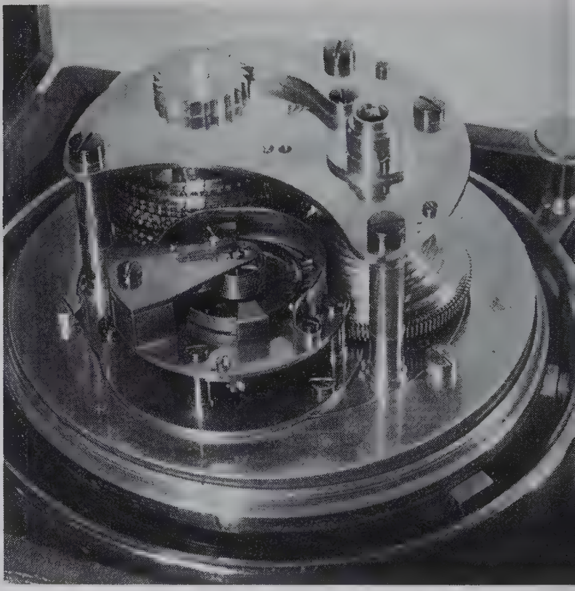

f

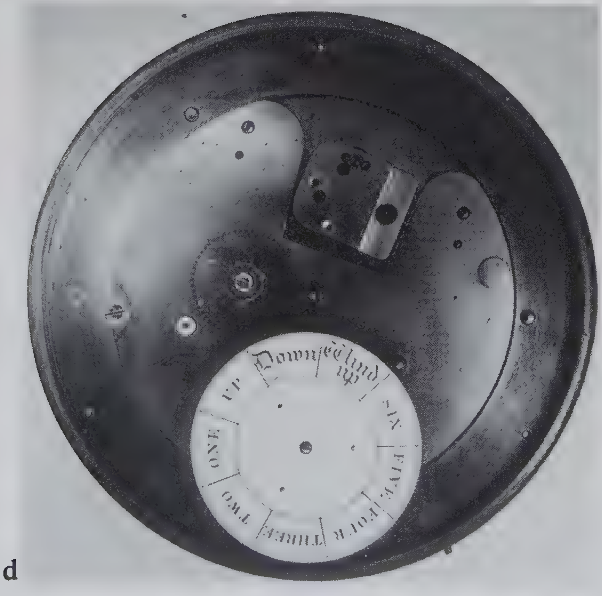
Plate 54

a. Cat. no. 81.
b. Cat. no. 82.
c. Cat. no. 82.
d. Cat. no. 82.
e. Cat. no. 82.


a


60
10
20
30
40
50
Barraud LONDON
Down
982
b


c


Down
UP
ONE
TWO
THREE
FOUR
FIVE
SIX
d

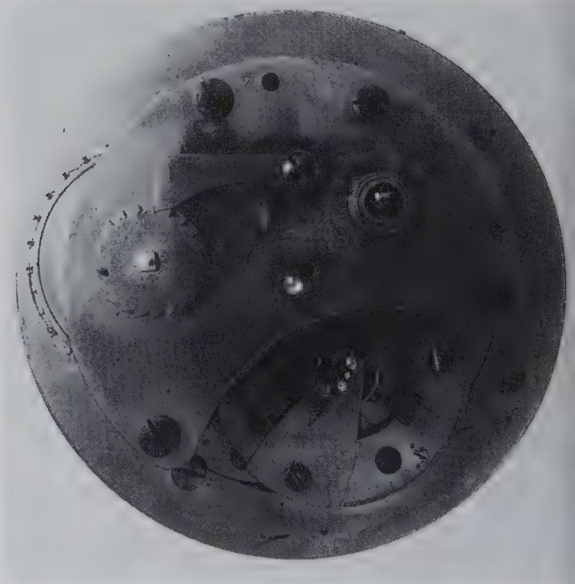
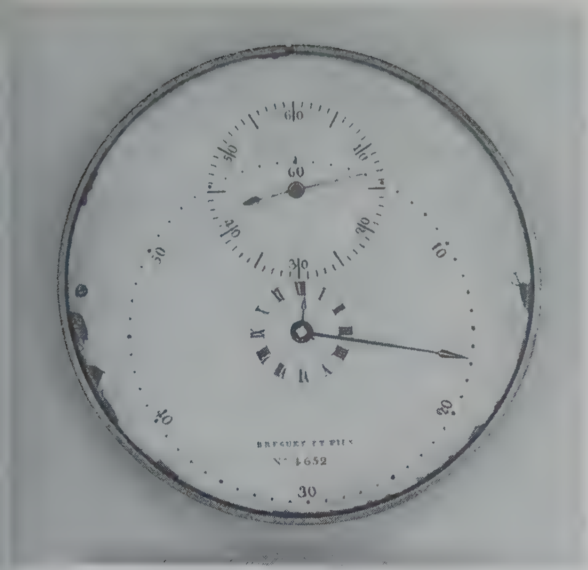
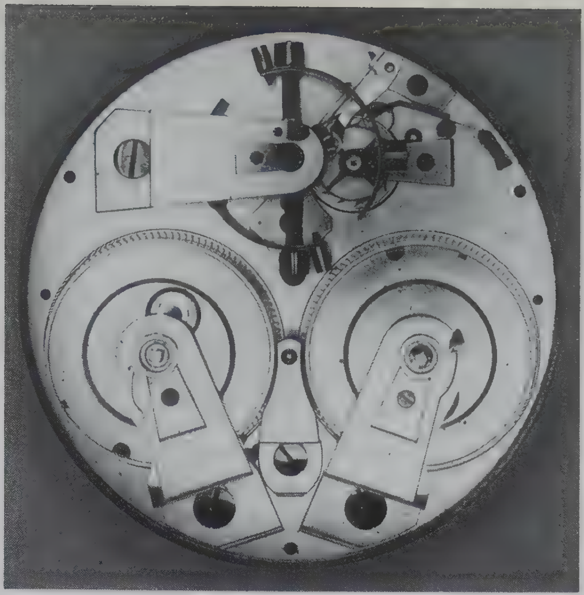

e

Plate 55

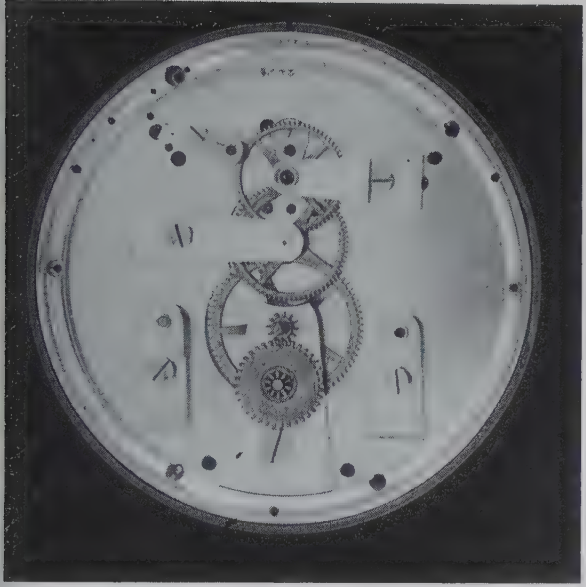
- **a.** Cat. no. 83.
- **b.** Cat. no. 83.
- **c.** Cat. no. 83.
- **d.** Cat. no. 83.
- **e.** Cat. no. 83.


BREGUET ET FILS
N° 4652

a

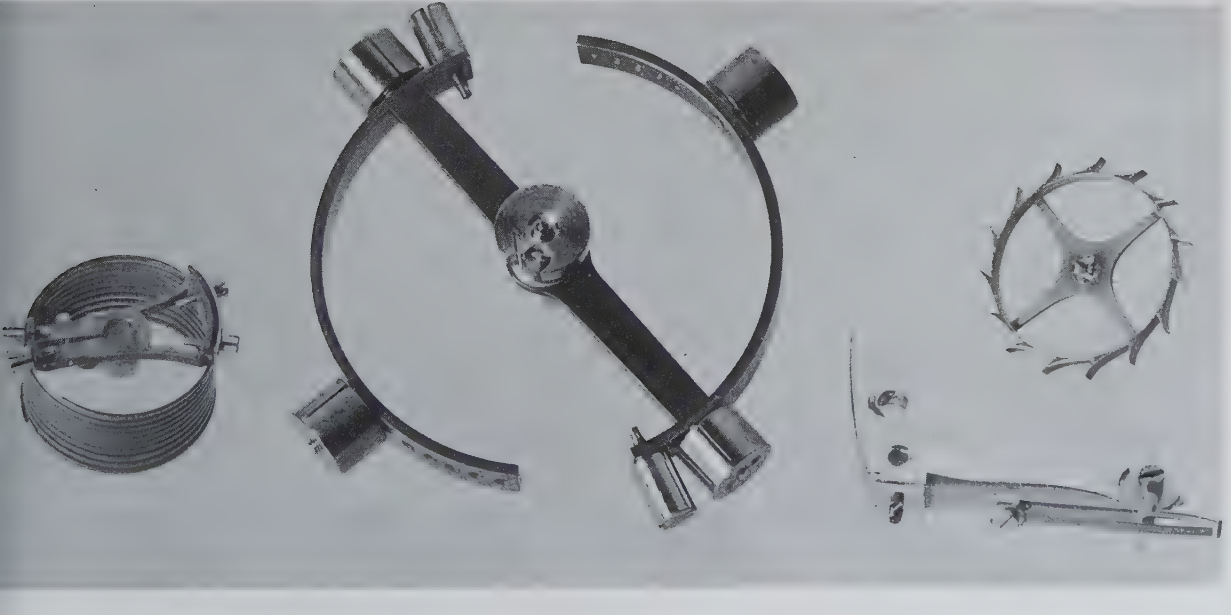


b



c

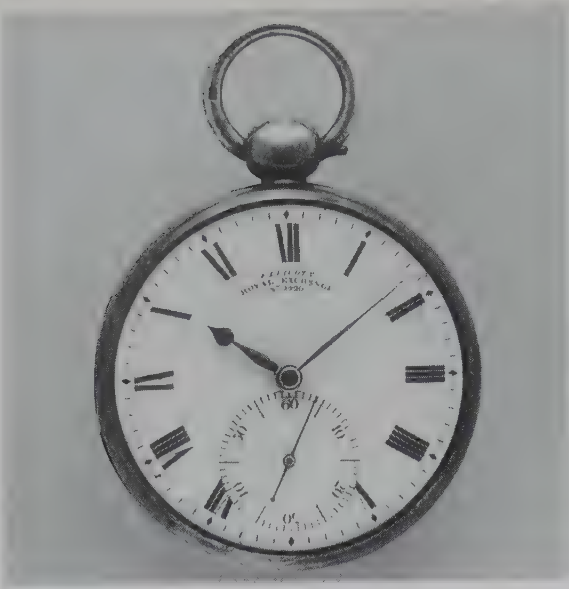
d

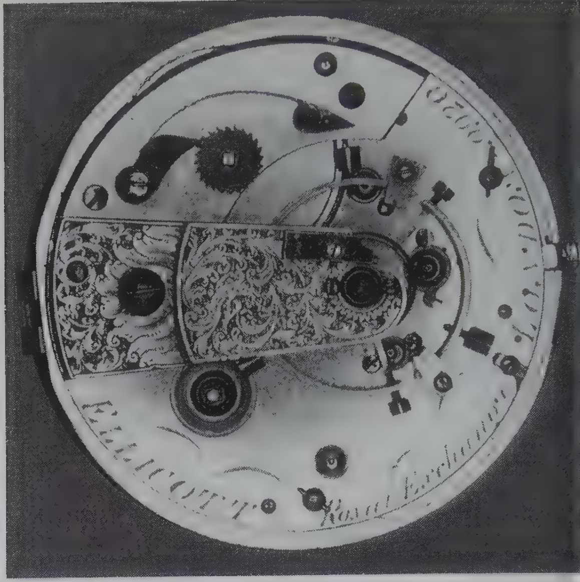


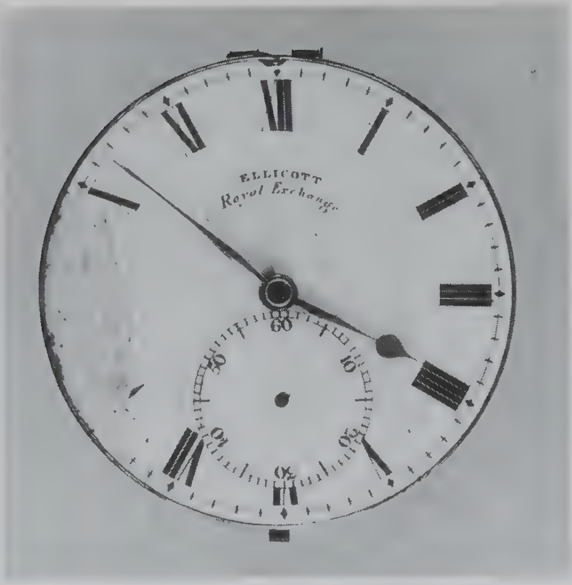
e

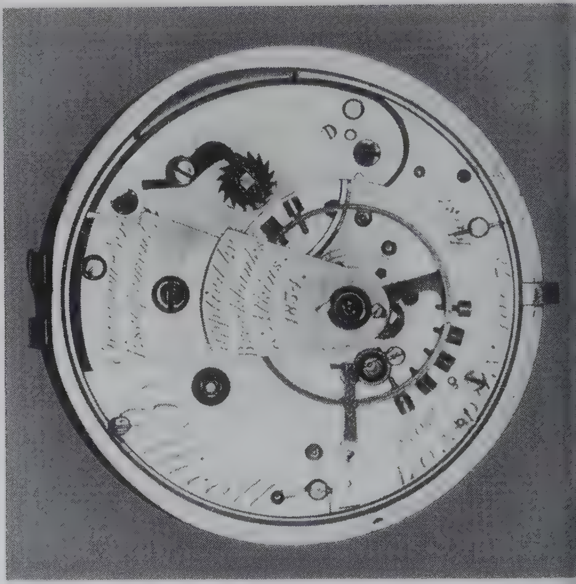
Plate 56

a. Cat. no. 84.
b. Cat. no. 84.
c. Cat. no. 85.
d. Cat. no. 85.
e. Cat. no. 86.
f. Cat. no. 86.

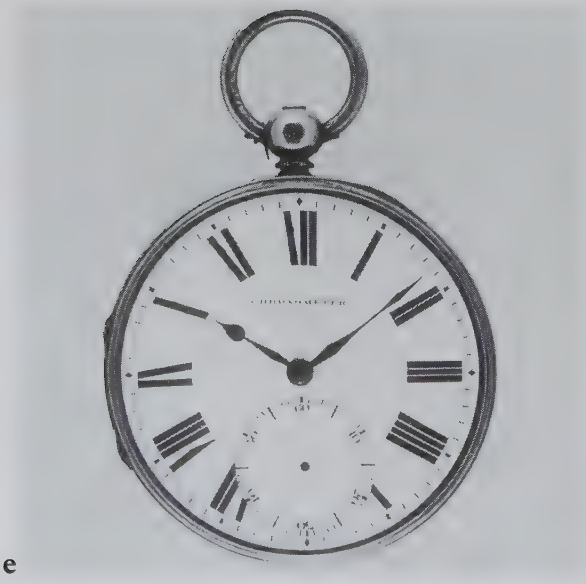

a

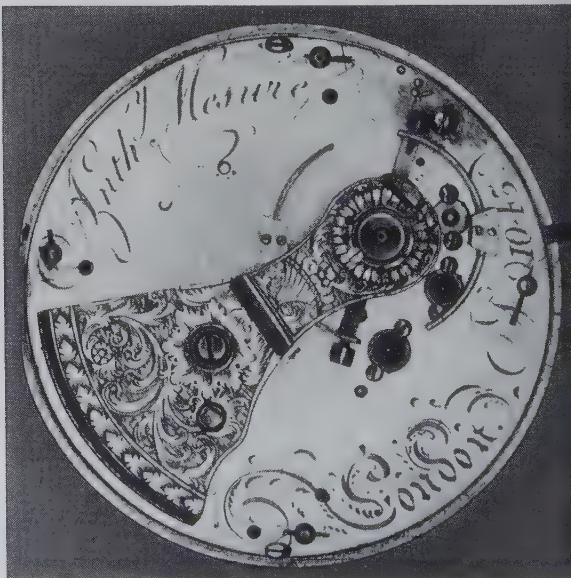

ELLICOTT
Royal Exchange
b


ELLICOTT
Royal Exchange
60
c



d

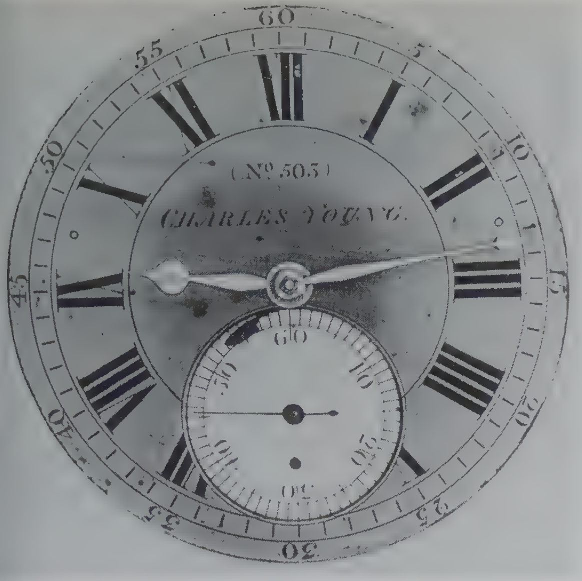

CHRONOMETER
e



f

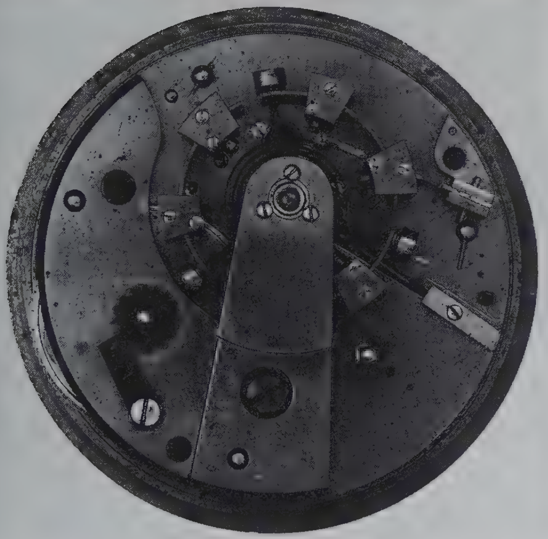
Plate 57

a. Cat. no. 87.
b. Cat. no. 87.
c. Cat. no. 87.
d. Cat. no. 87.
e. Cat. no. 87.
The piece second from the right is the resilient stud.

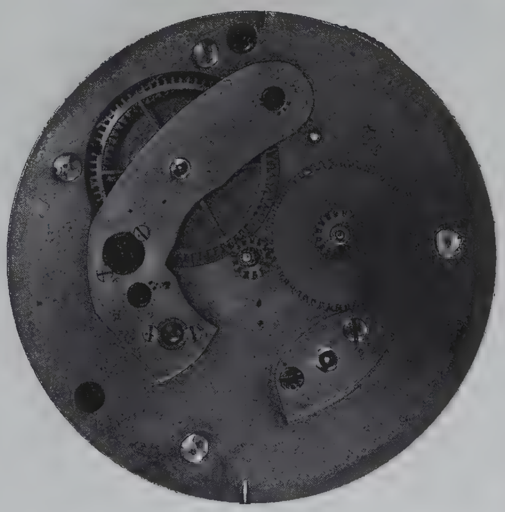

(Nº 503)
CHARLES YOUNG

a

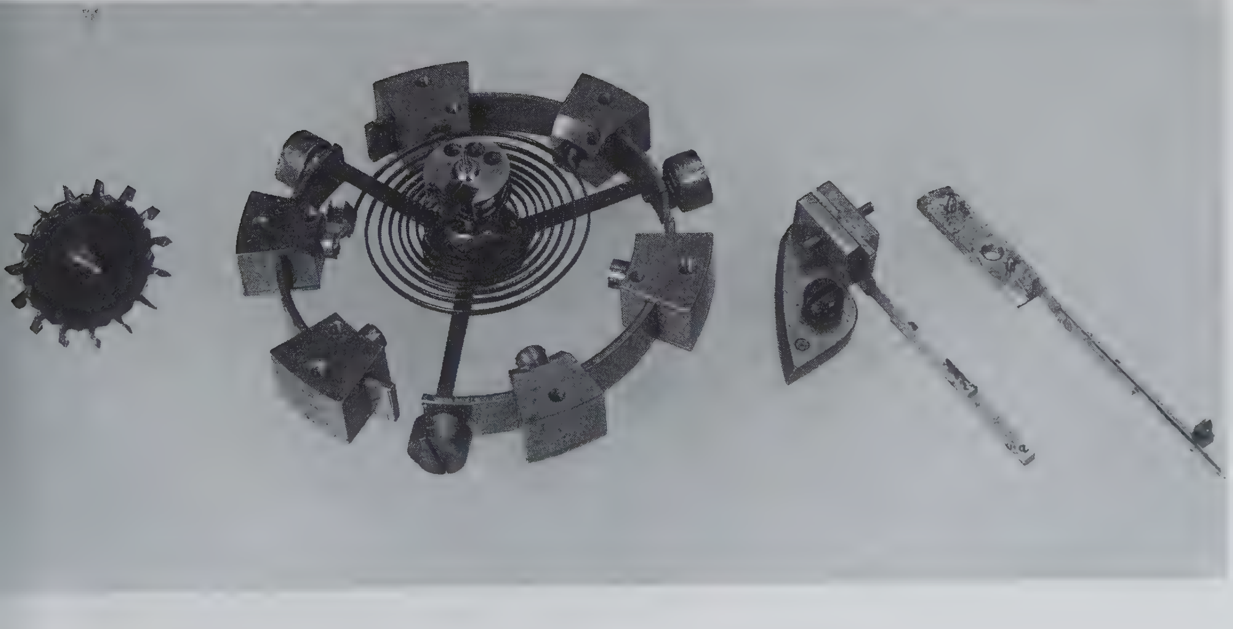
b



c



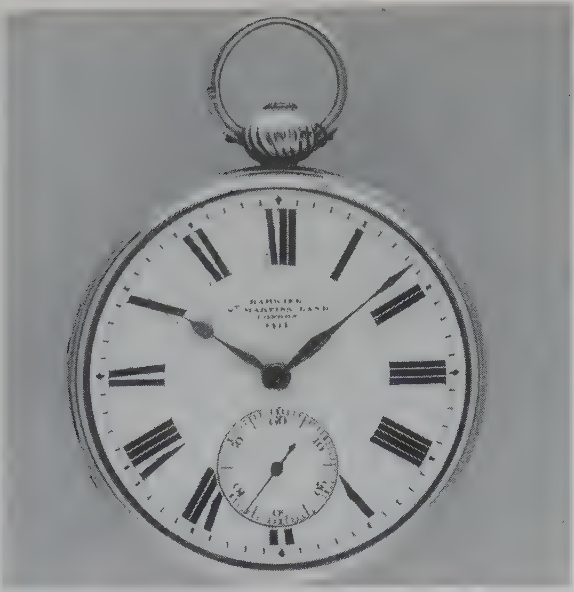
d



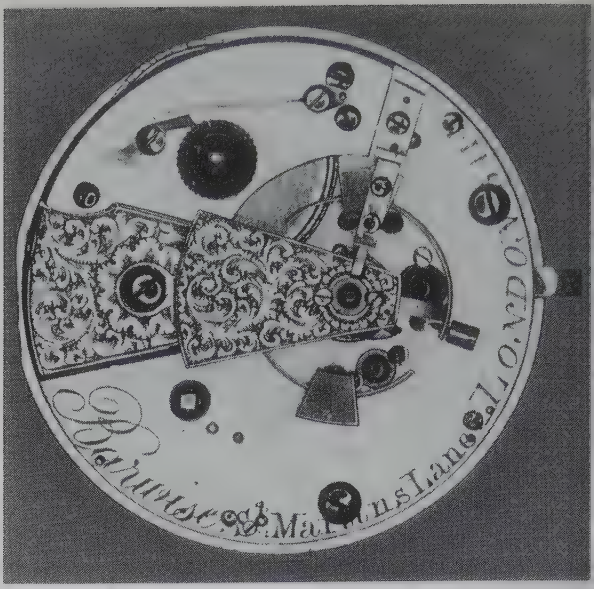
e

Plate 58

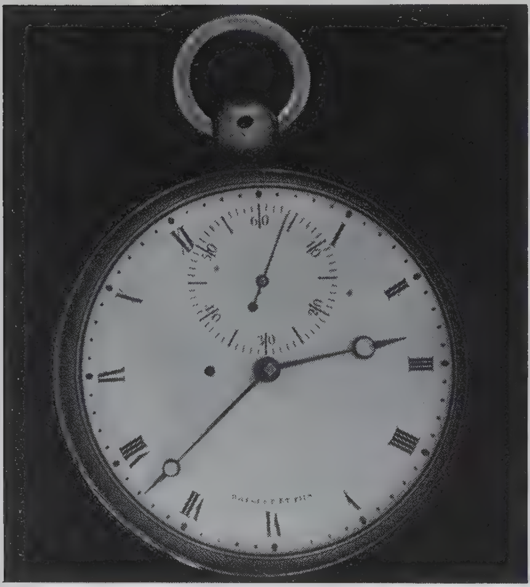
a. Cat. no. 88.
b. Cat. no. 88.
c. Cat. no. 89.
d. Cat. no. 89.
e. Cat. no. 89.


BARWISE
ST MARTINS LANE
LONDON

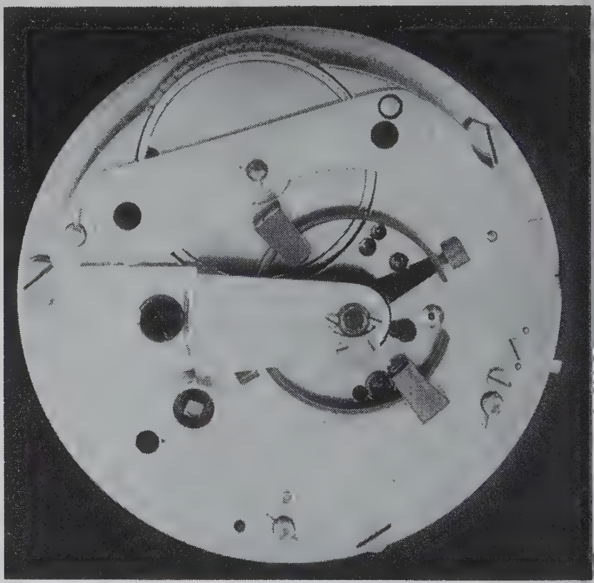
a


Barwise St Martins Lane LONDON

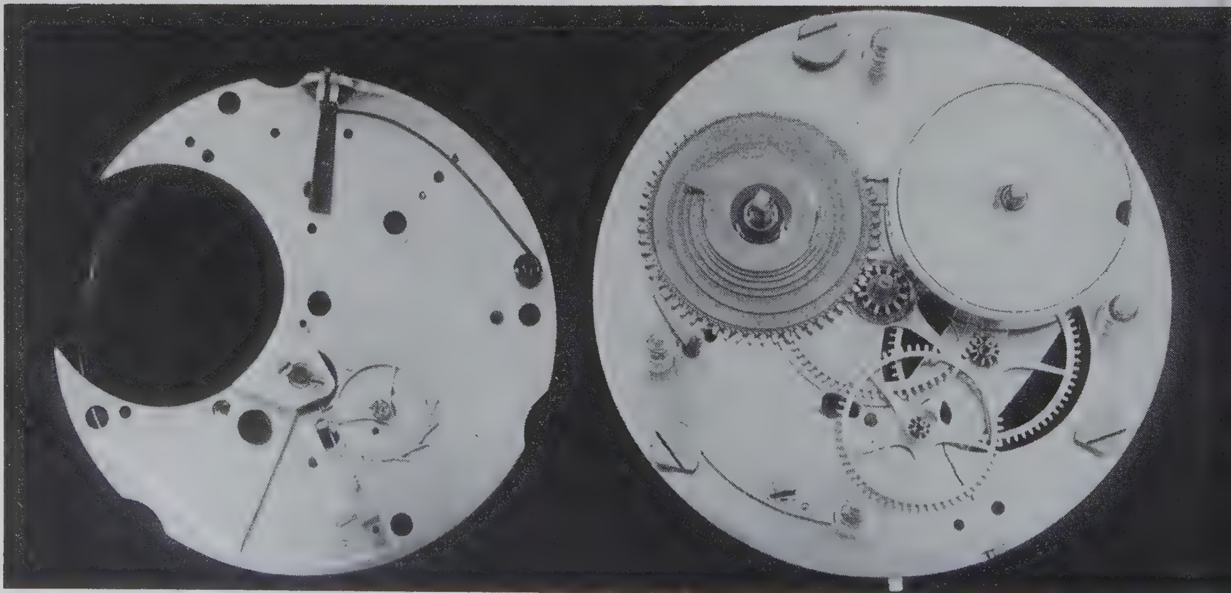
b



c



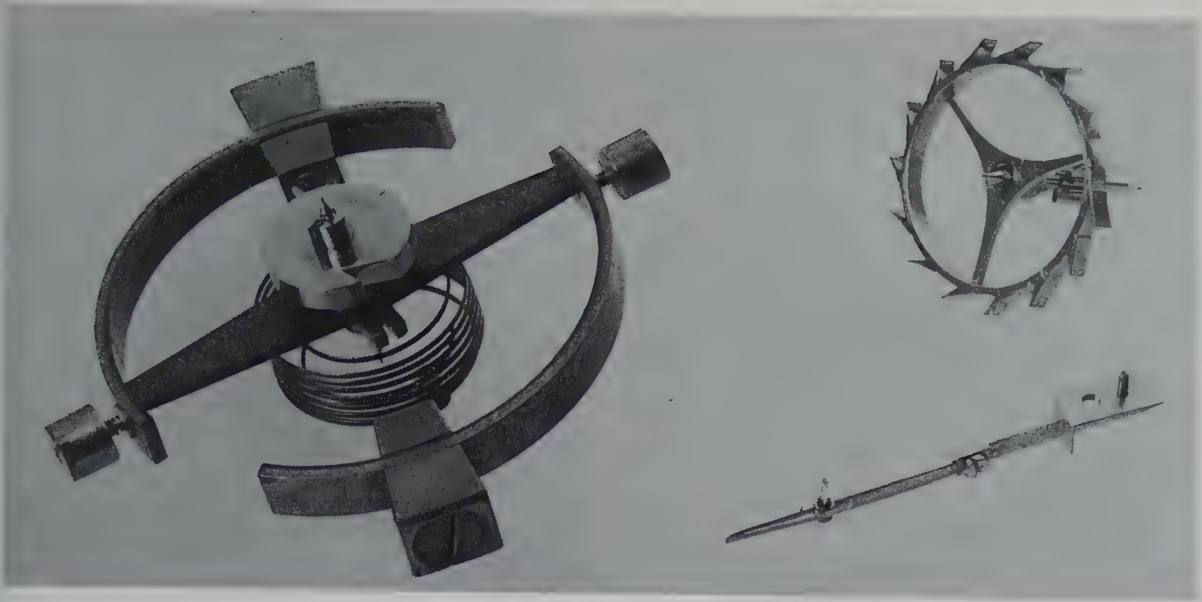
d

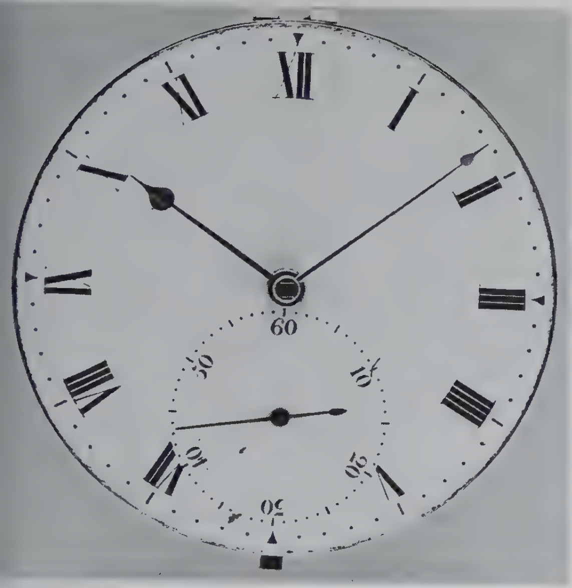


e

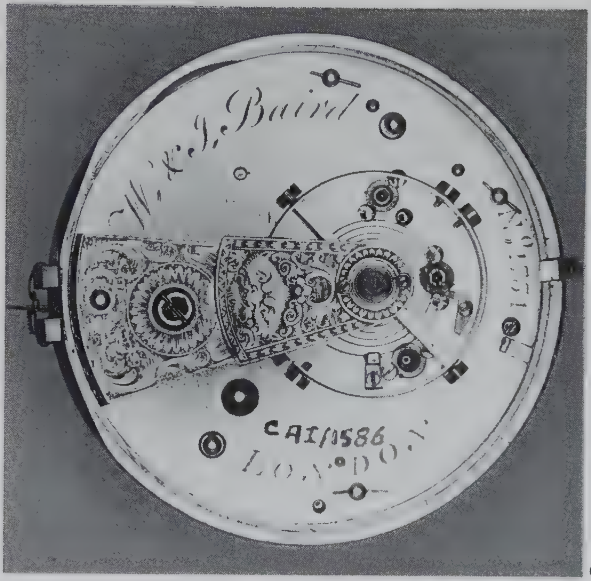
Plate 59

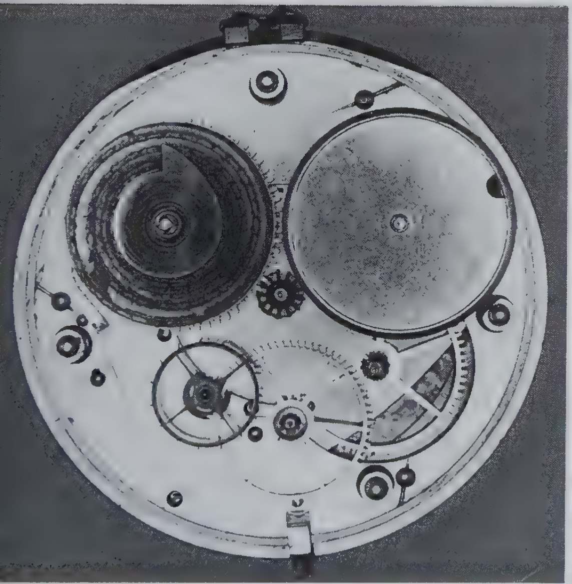
a. Cat. no. 89.
b. Cat. no. 90.
c. Cat. no. 90.
d. Cat. no. 90.
e. Cat. no. 90.


a



b


W. & J. Baird
CAI/1586
LONDON
c


d

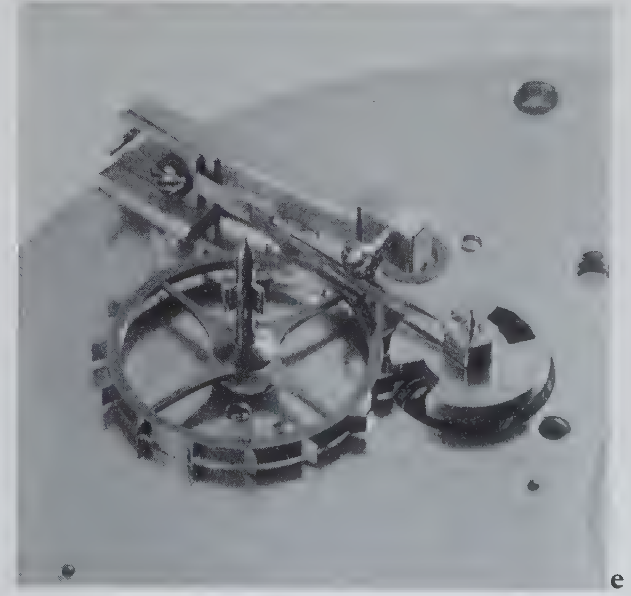
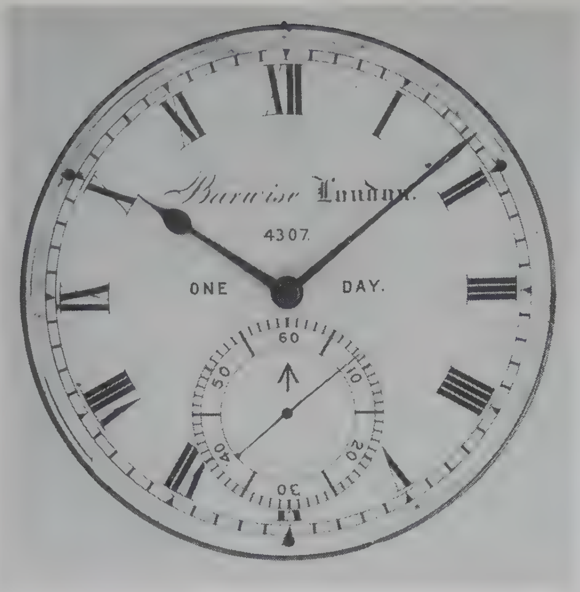
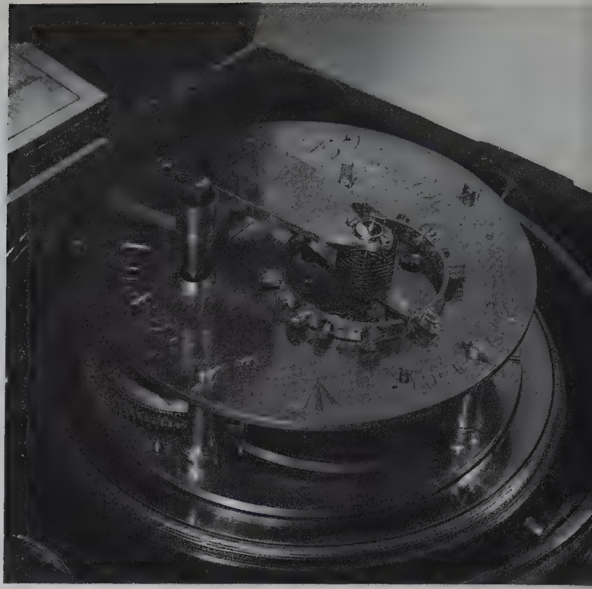

e

Plate 60

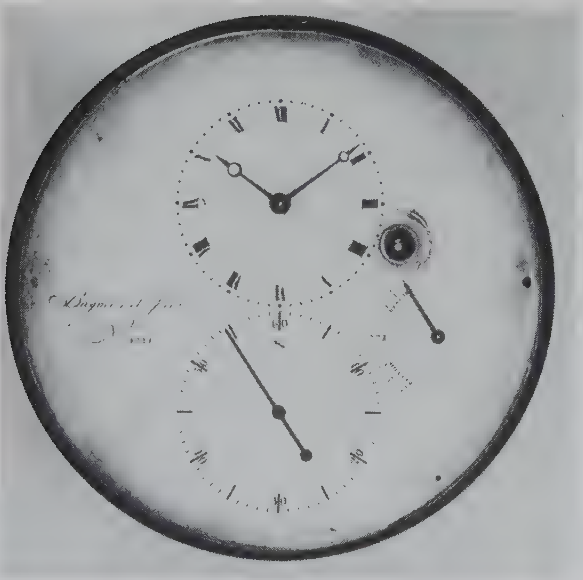
a. Cat. no. 91.
b. Cat. no. 91.
c. Cat. no. 92.
d. Cat. no. 92.
e. Cat. no. 92.
f. Cat. no. 92.
The ratchet-tooth wheel on the right is the up-and-down wheel.


Barwise London
4307
ONE
DAY
60
10
20
30
40
50

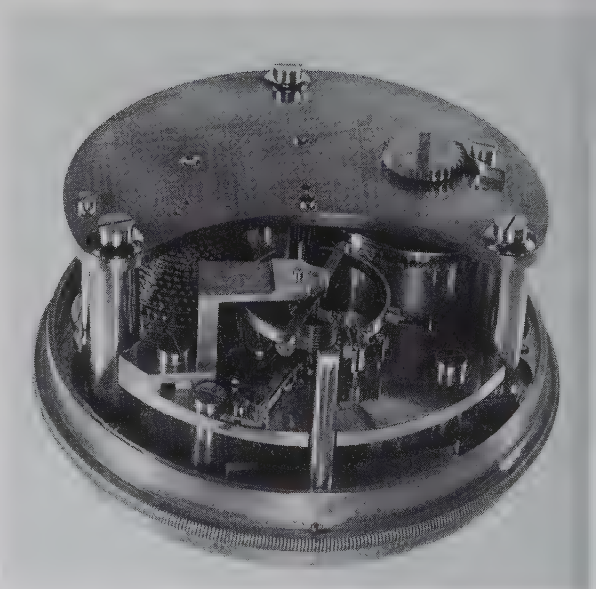
a



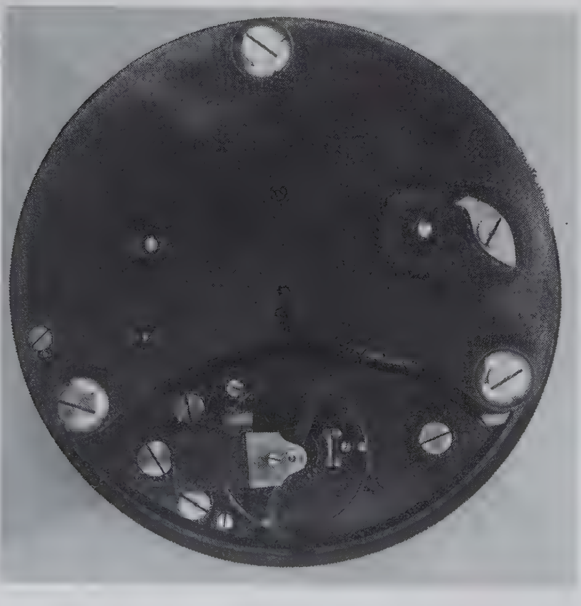
b



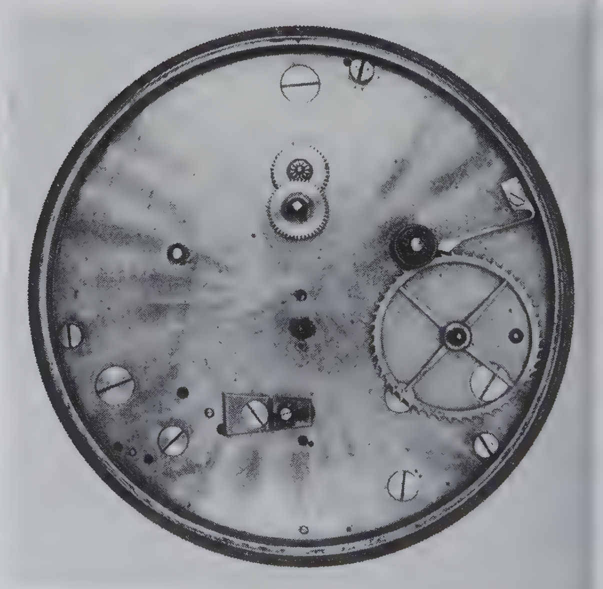
c



d



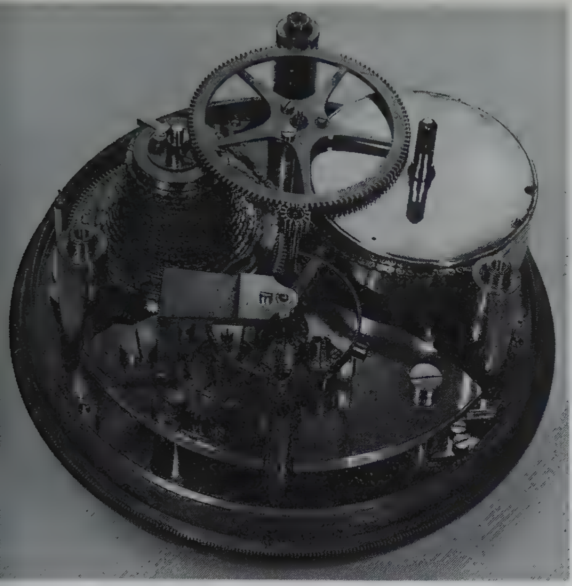
e

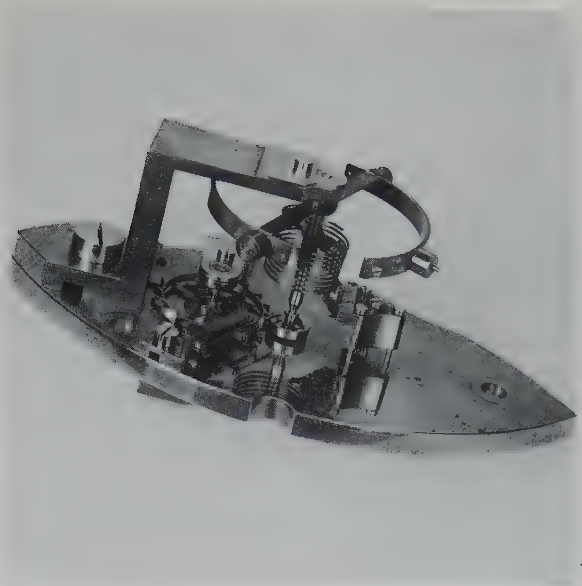


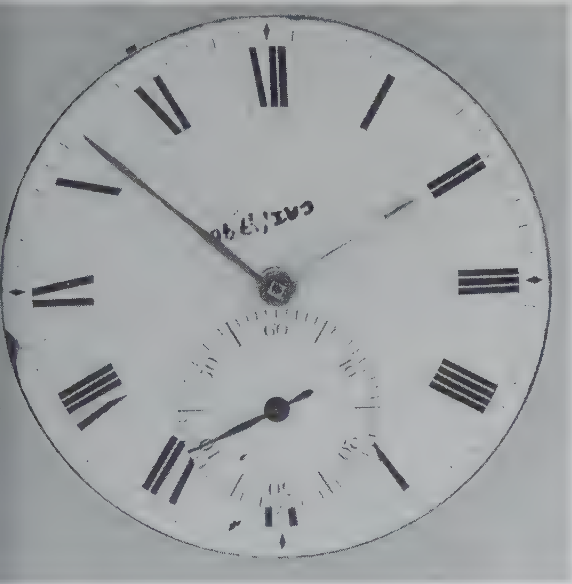
f

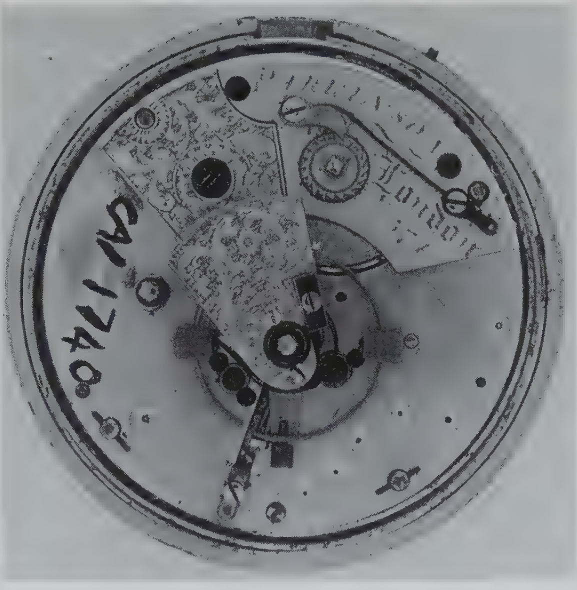
Plate 61

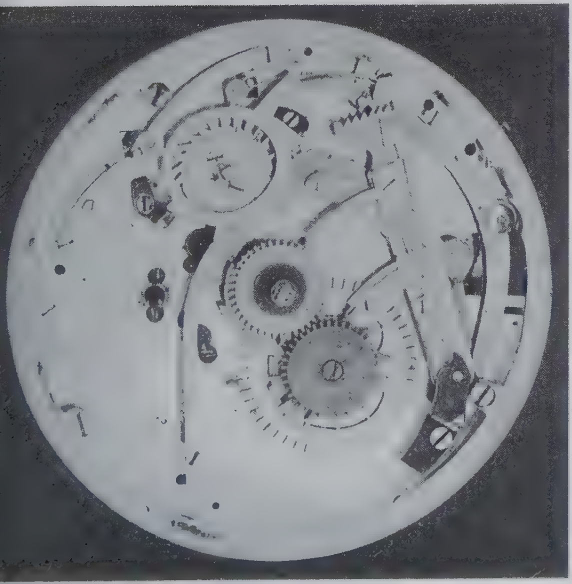
a. Cat. no. 92.
b. Cat. no. 92.
c. Cat. no. 93.
d. Cat. no. 93.
e. Cat. no. 93.
f. Cat. no. 93.


a


b


c


CAT 1740
London
d


e

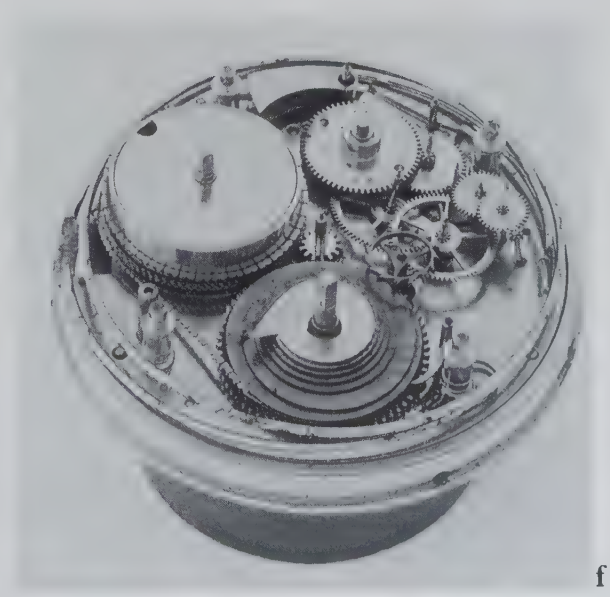
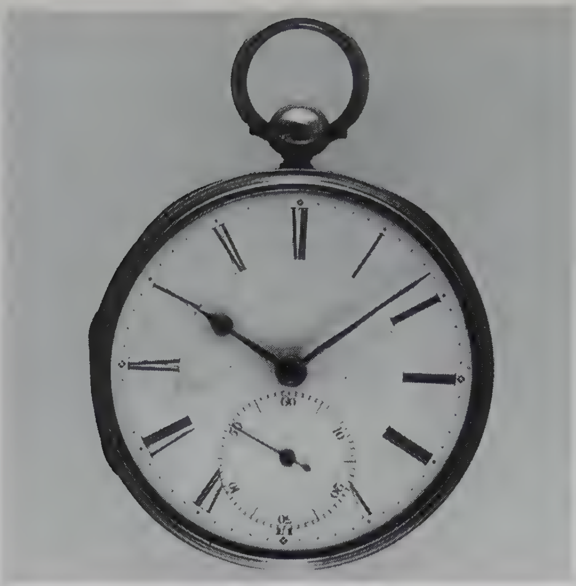
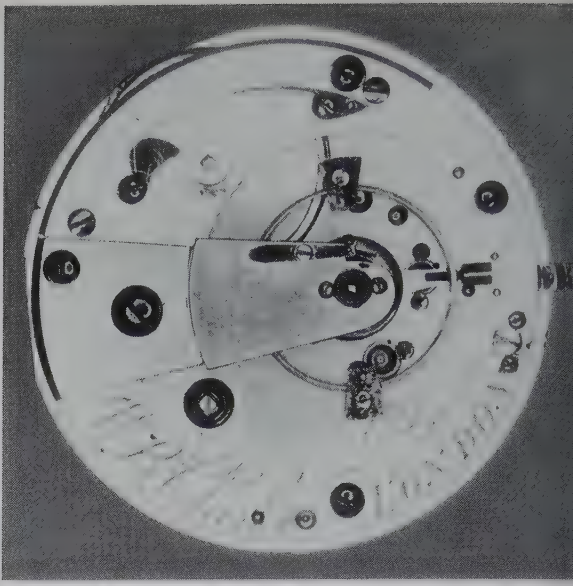
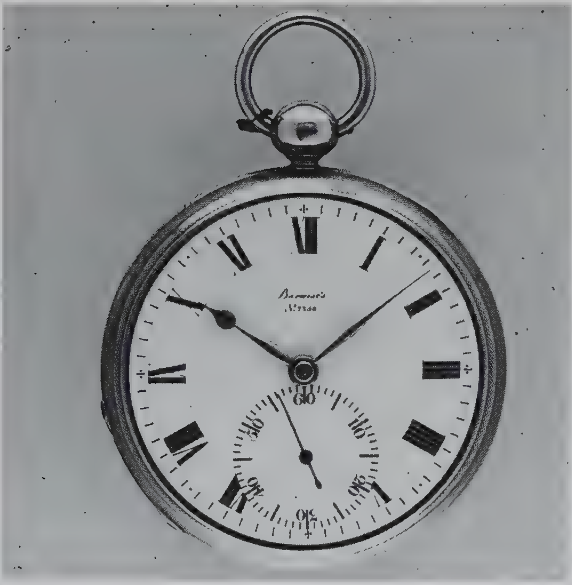

f

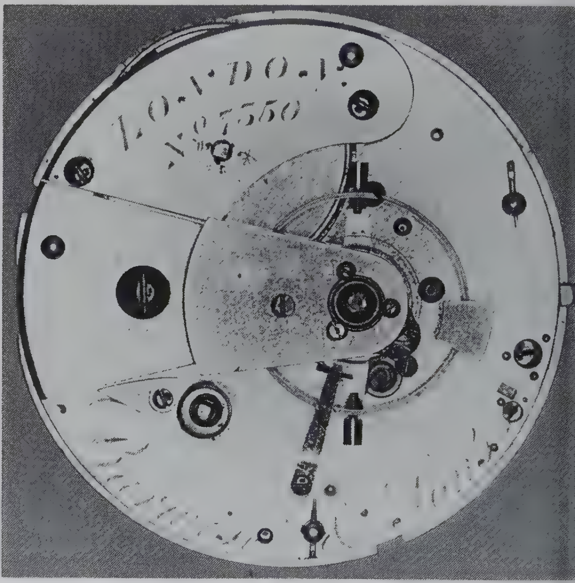
Plate 62

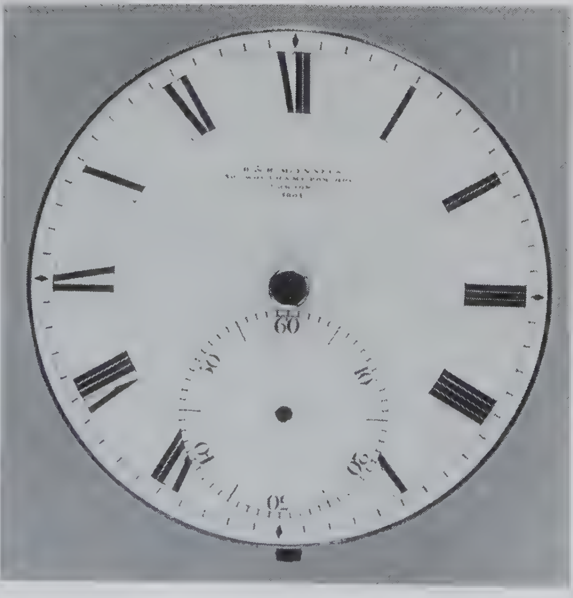
a. Cat. no. 94.
b. Cat. no. 94.
c. Cat. no. 95.
d. Cat. no. 95.
e. Cat. no. 96.
f. Cat. no. 96.

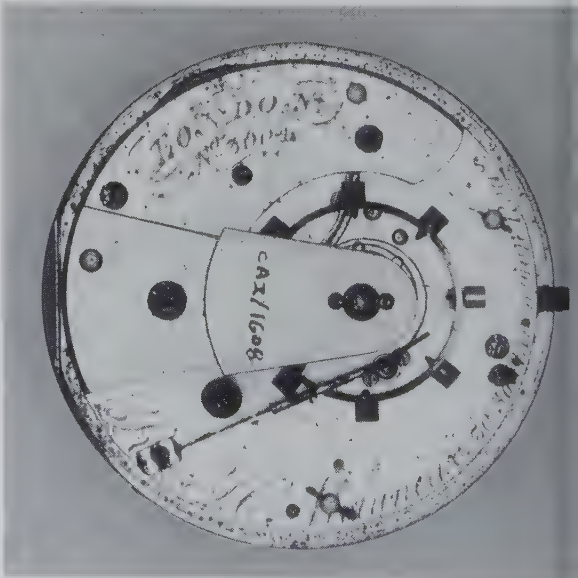

a


b

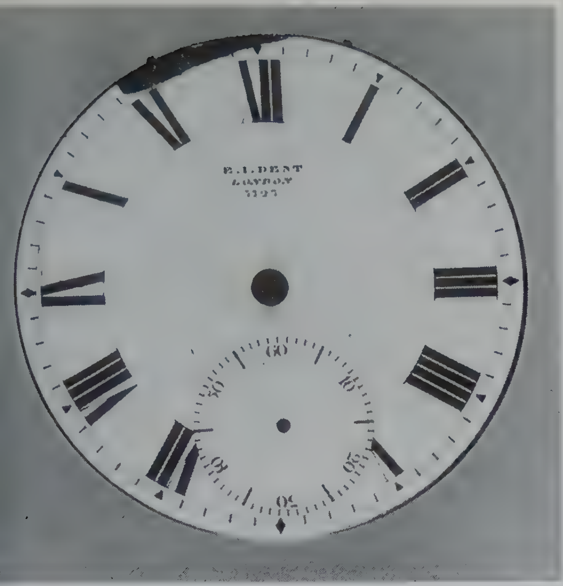

c


d

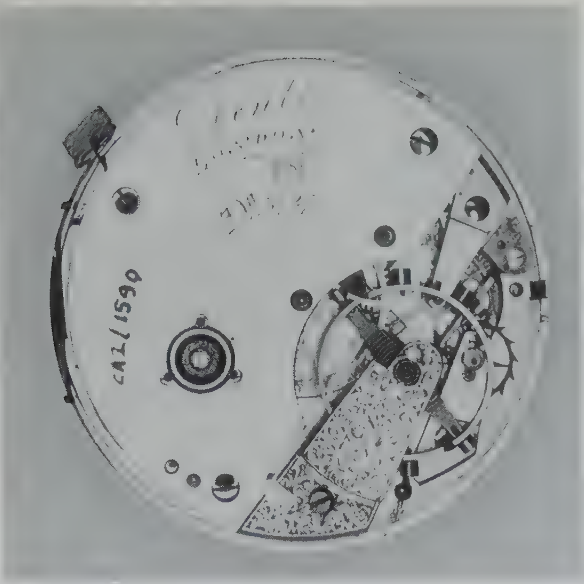

e


f

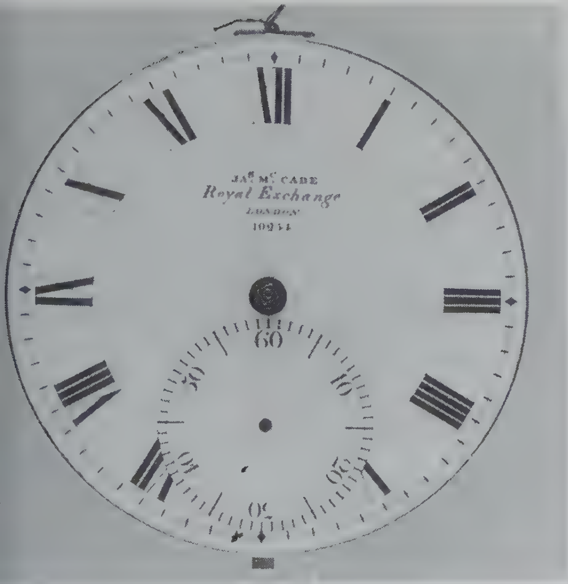
- **a.** Cat. no. 97.
- **b.** Cat. no. 97.
- **c.** Cat. no. 98.
- **d.** Cat. no. 98.
- **e.** Cat. no. 98.
- **f.** Cat. no. 98.


E.J. DENT
LONDON
60
10
20
30
40
50

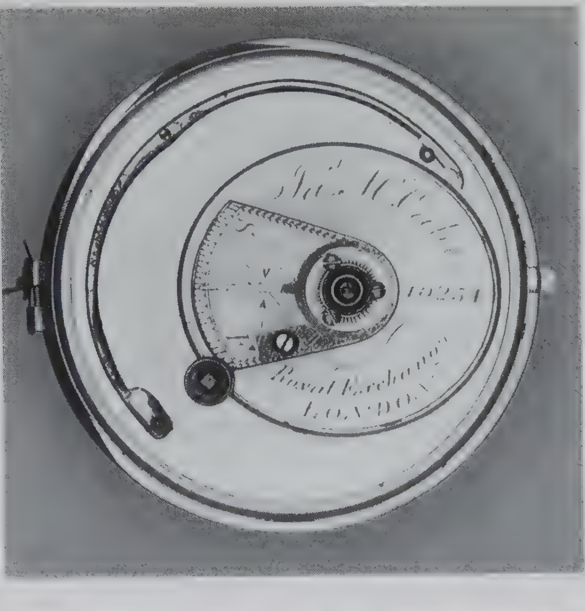
a


Dent
LONDON
CA2/1590

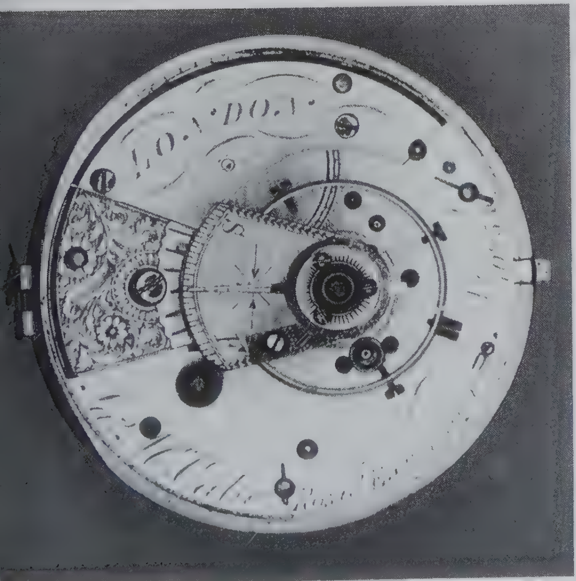
b


JAS. McCABE
Royal Exchange
LONDON
10254
60
10
20
30
40
50

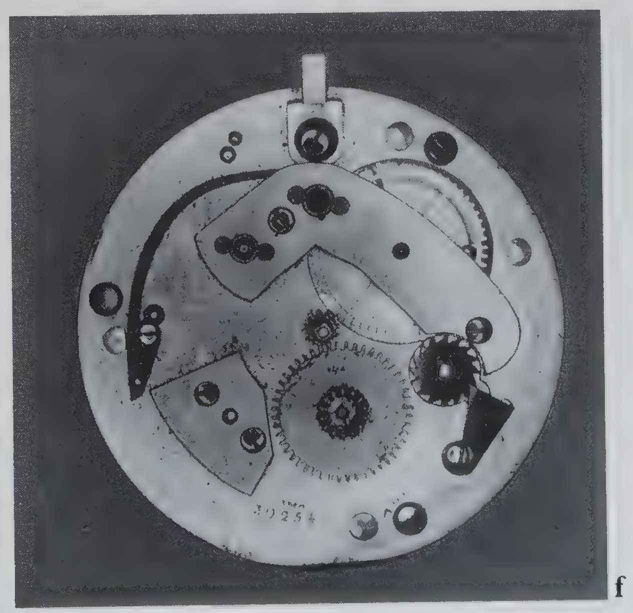
c


Jas. McCabe
10254
Royal Exchange
LONDON
S
F

d



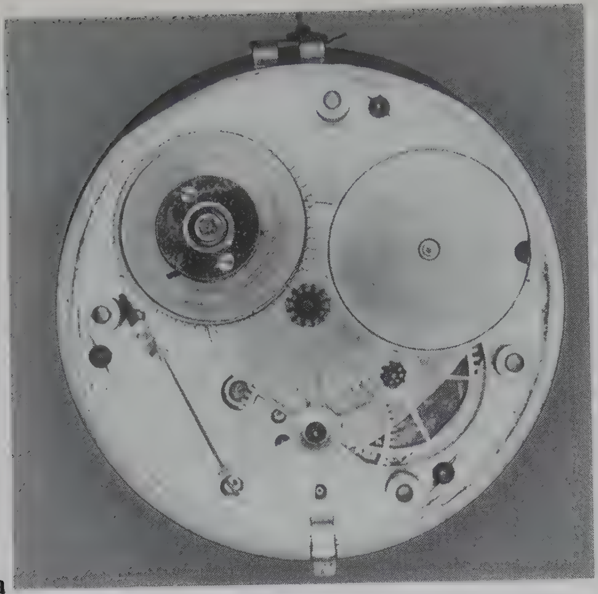
e

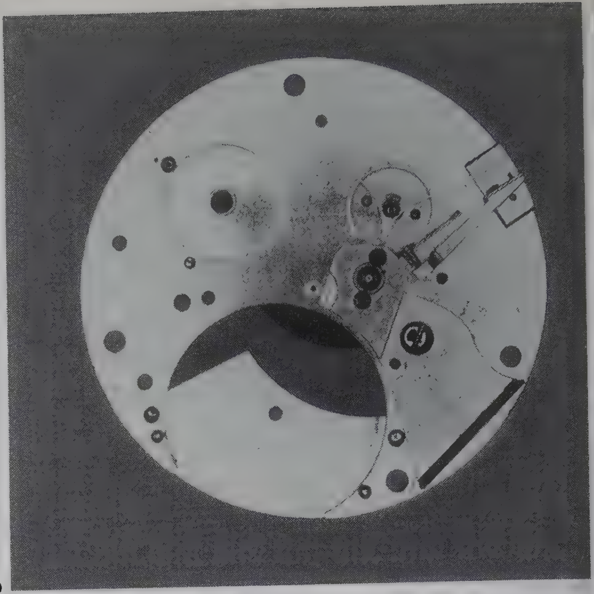


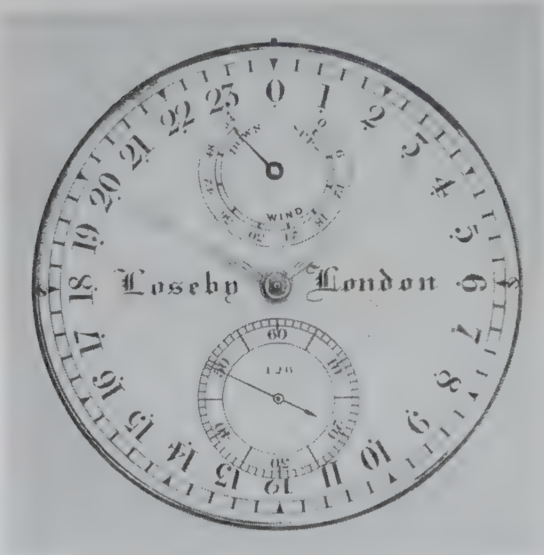
f

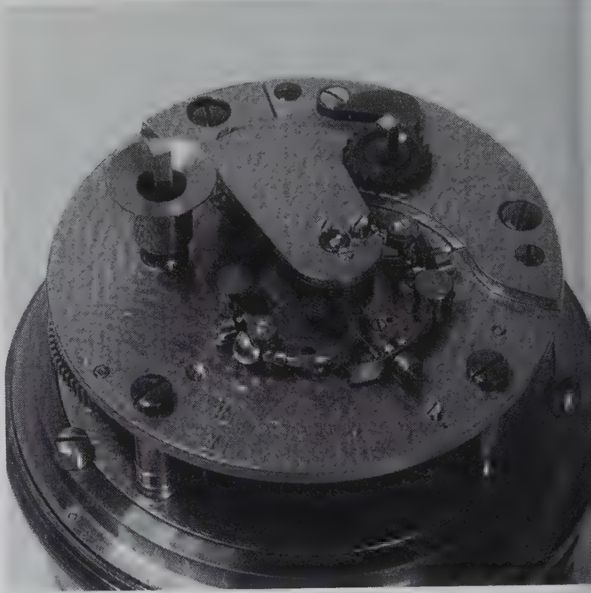
Plate 64

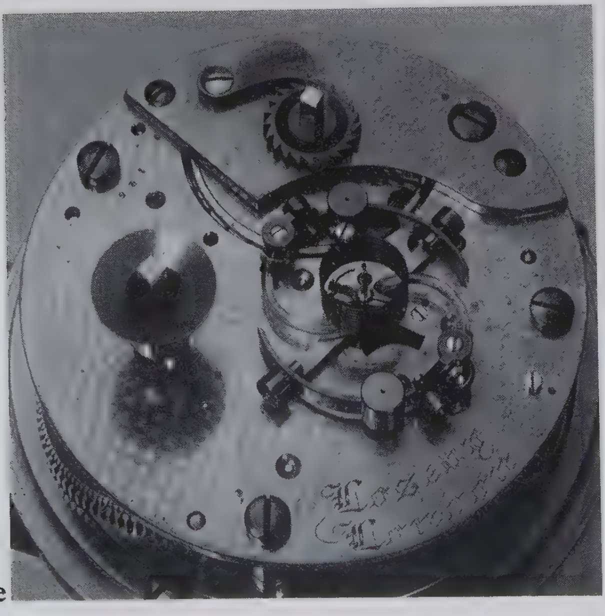
a. Cat. no. 98.
b. Cat. no. 98.
c. Cat. no. 99.
d. Cat. no. 99.
e. Cat. no. 99.
f. Cat. no. 99.


a


b


Loseby London
UP
DOWN
WIND
60
126
30
c


d



e

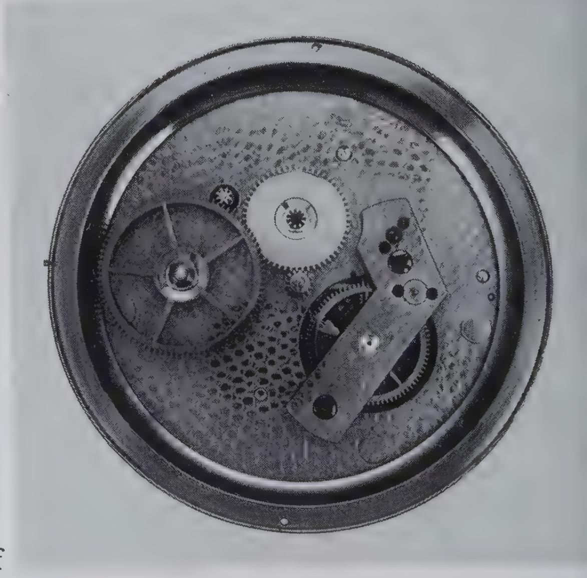
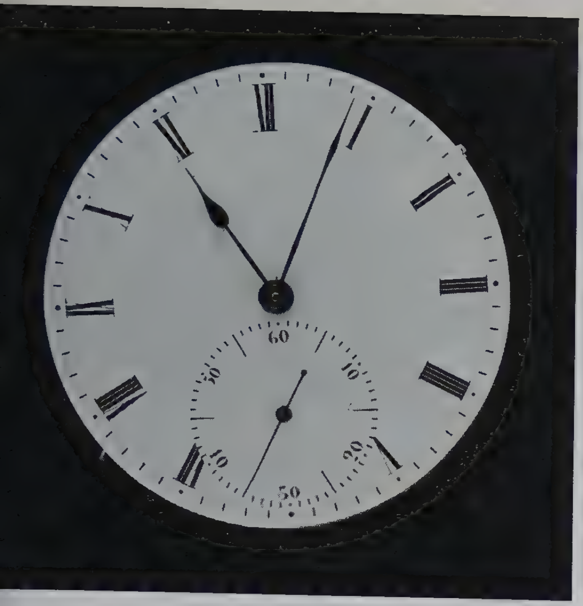
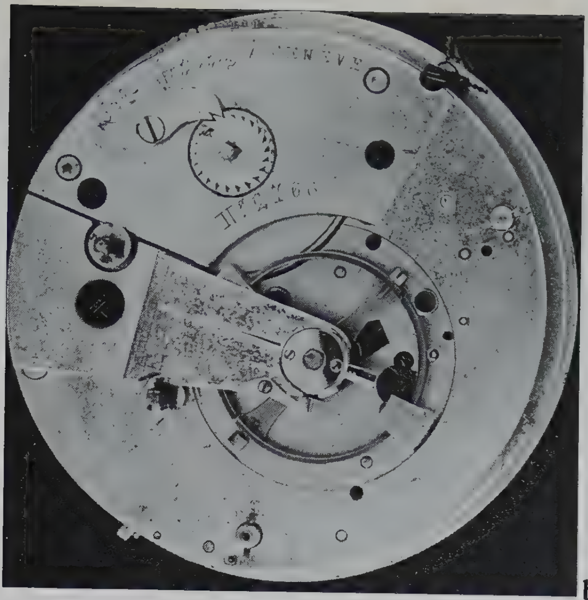
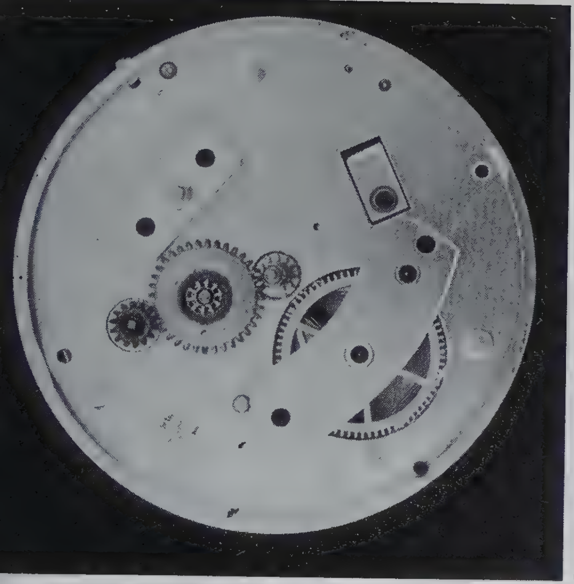

f

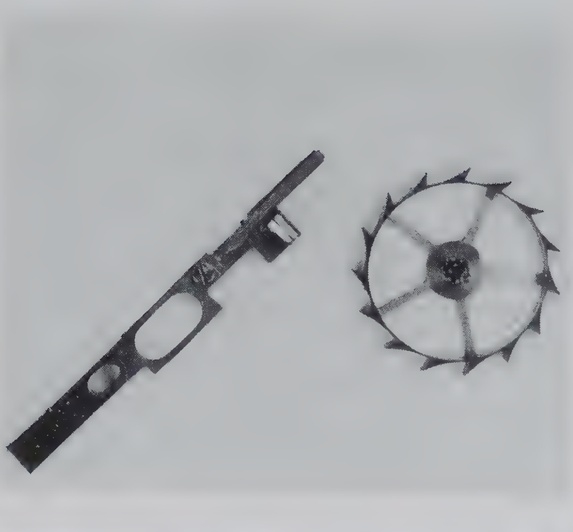
Plate 65

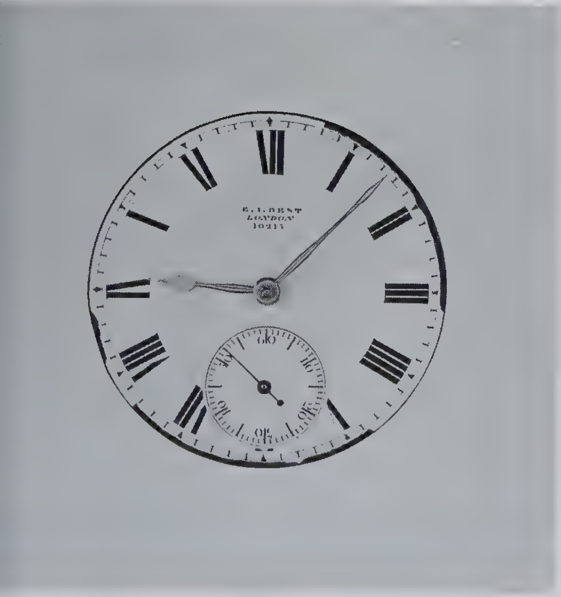
a. Cat. no. 100.
b. Cat. no. 100.
c. Cat. no. 100.
d. Cat. no. 100.
e. Cat. no. 101.
f. Cat. no. 101.


a


b


c


d


E. J. DENT
LONDON
10215
e

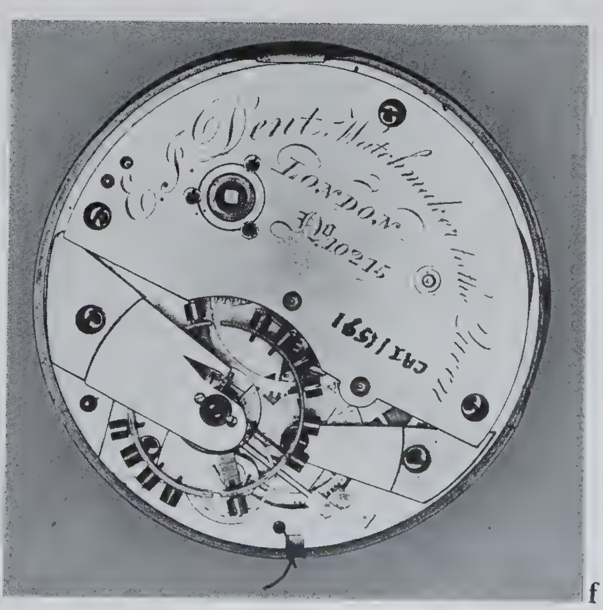
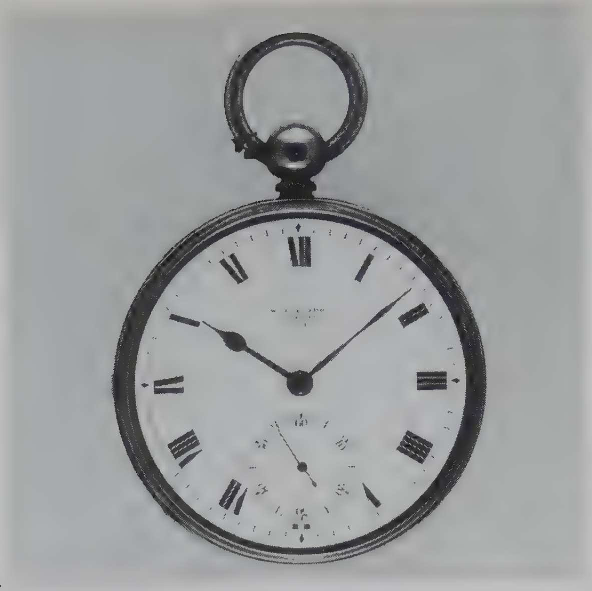
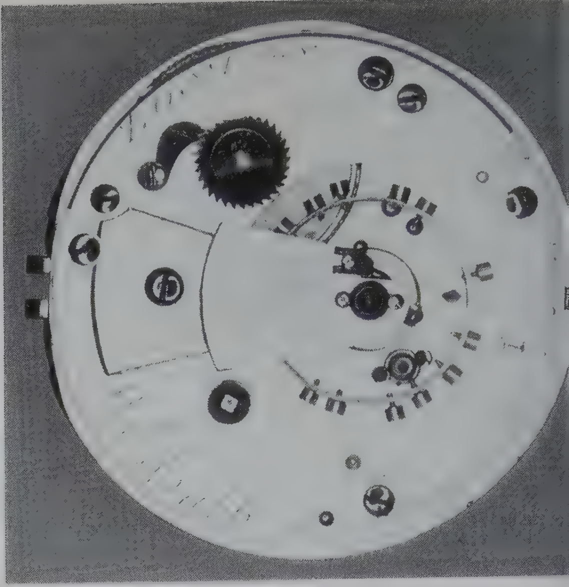
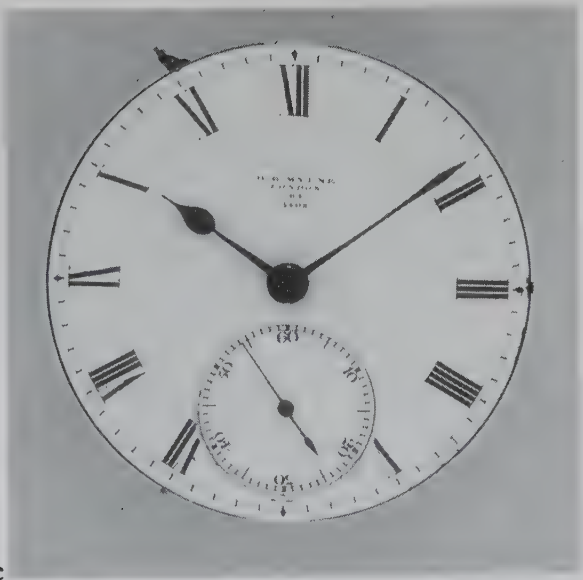

E. J. Dent Watchmaker to the Queen
LONDON
No 10215
CAT 1591
f

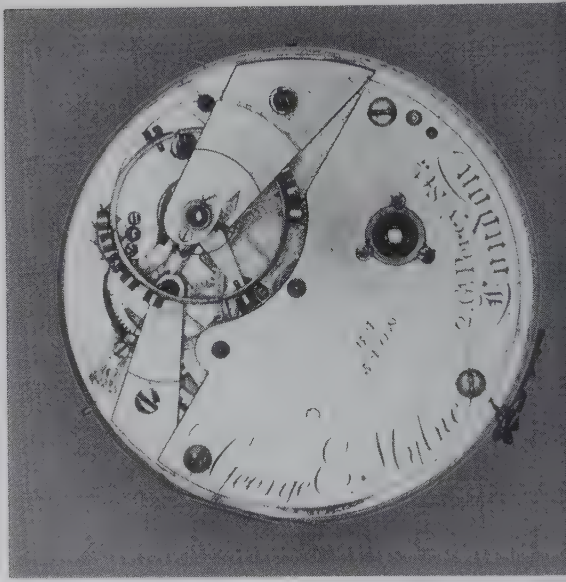
Plate 66

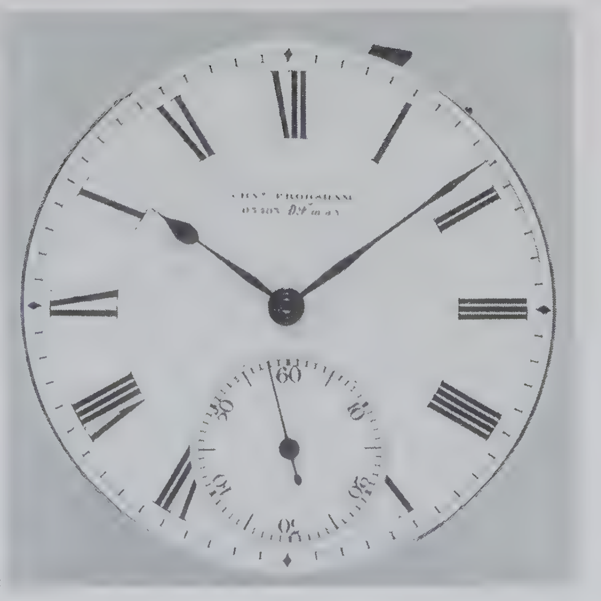
- **a.** Cat. no. 102.
- **b.** Cat. no. 102.
- **c.** Cat. no. 103.
- **d.** Cat. no. 103.
- **e.** Cat. no. 104.
- **f.** Cat. no. 104.


a


b


c


d


e

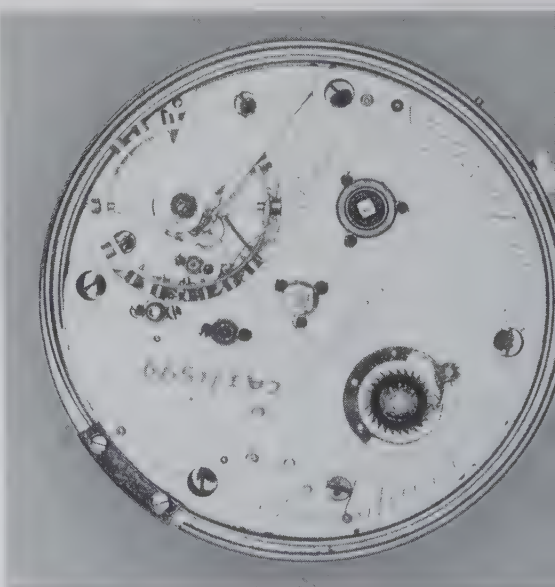
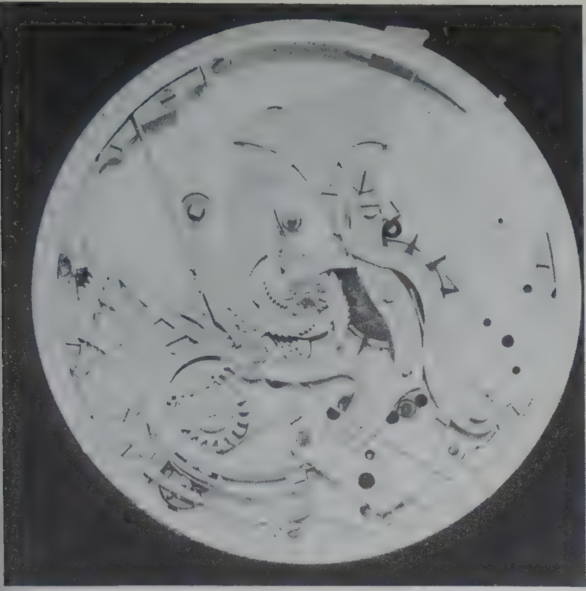
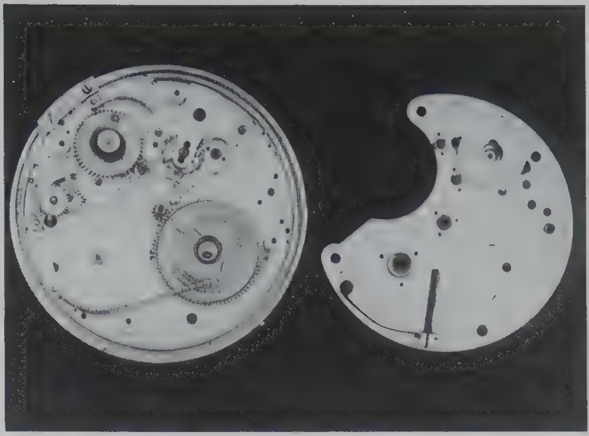
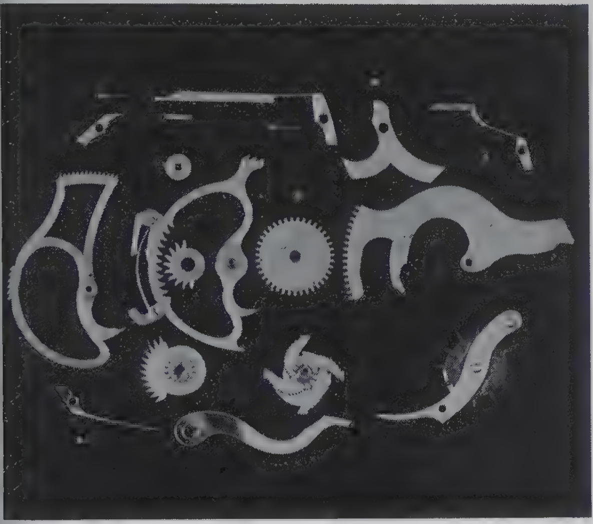

f

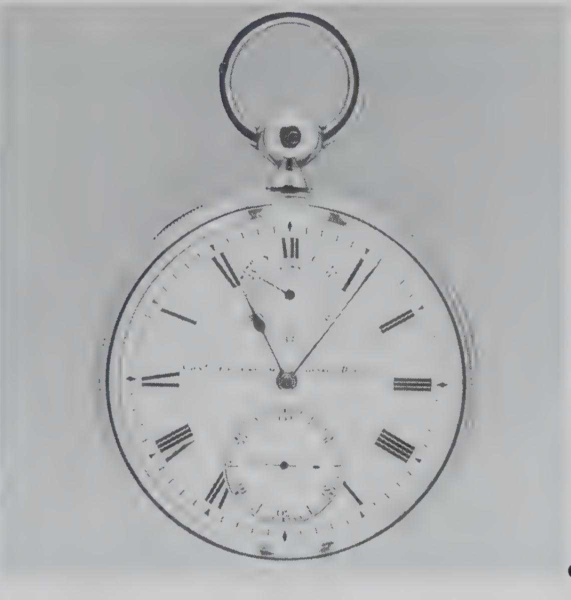
Plate 67

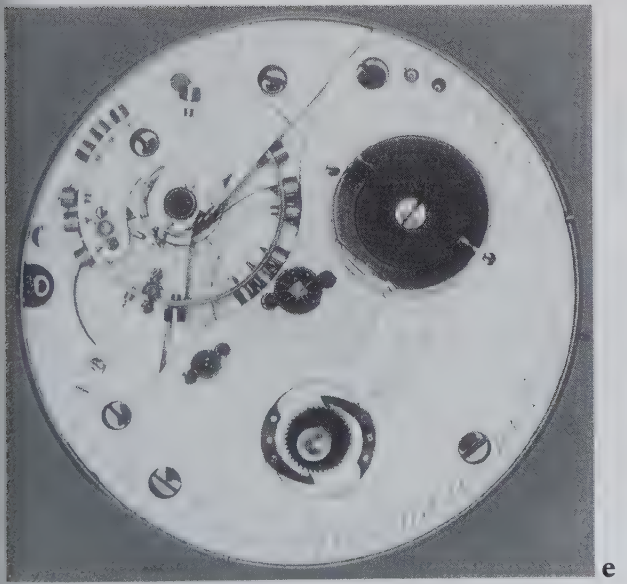
a. Cat. no. 104.
b. Cat. no. 104.
c. Cat. no. 104.
d. Cat. no. 105.
e. Cat. no. 105.
f. Cat. no. 105, under dial.


a


b


c


d


e

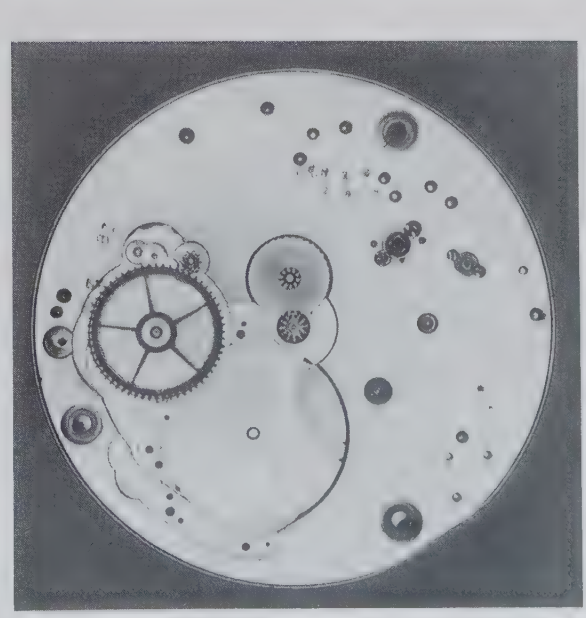
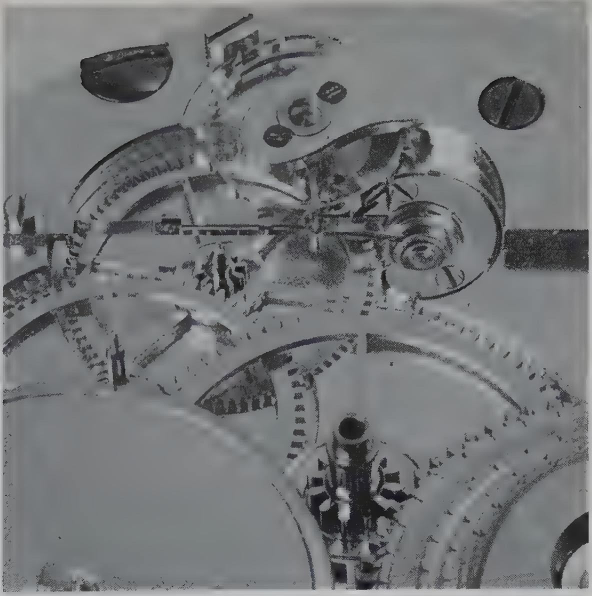
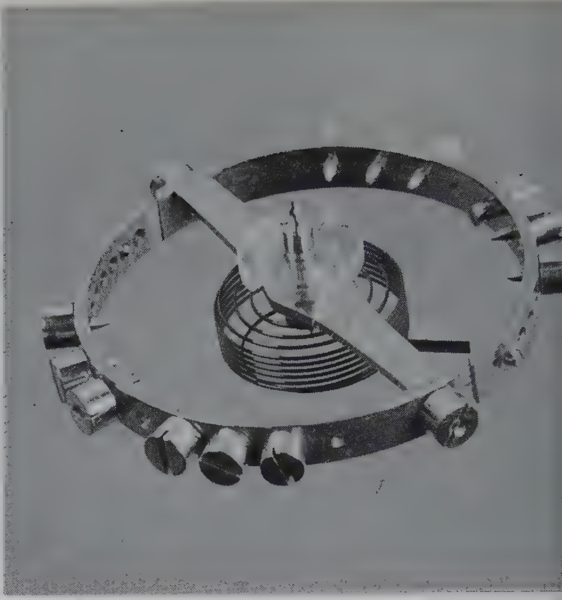
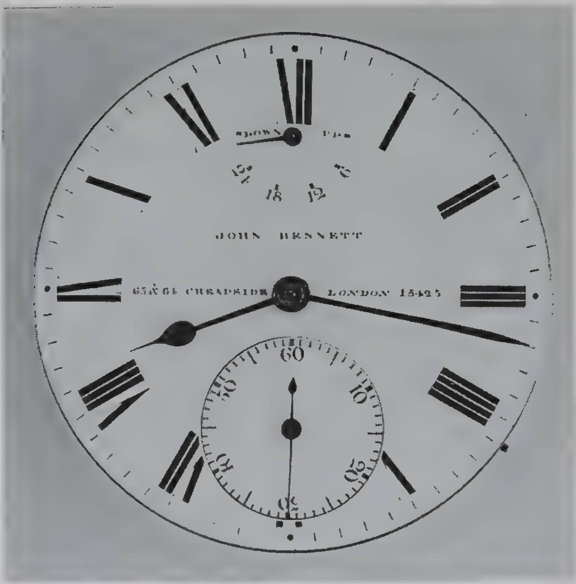

f

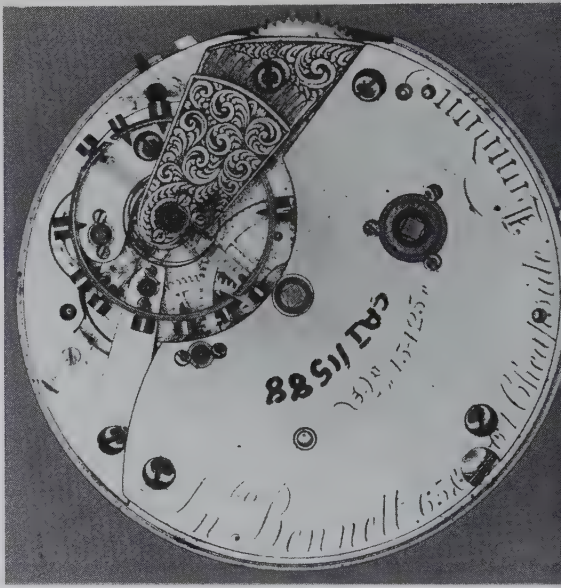
Plate 68

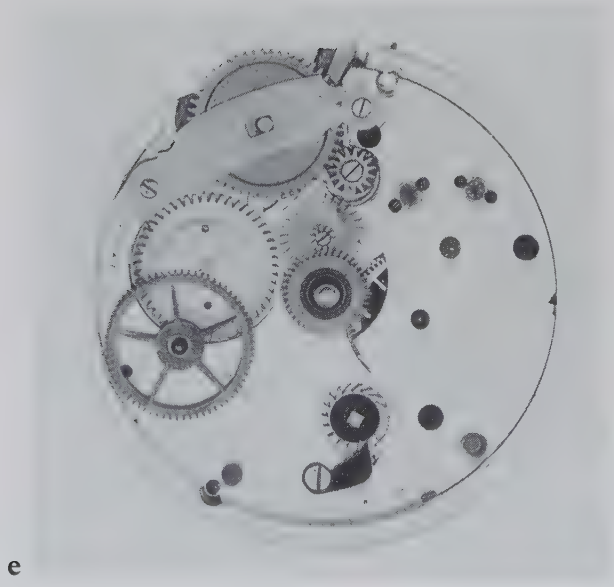
- **a.** Cat. no. 105.
- **b.** Cat. no. 105.
- **c.** Cat. no. 106.
- **d.** Cat. no. 106.
- **e.** Cat. no. 106.
- **f.** Cat. no. 106.

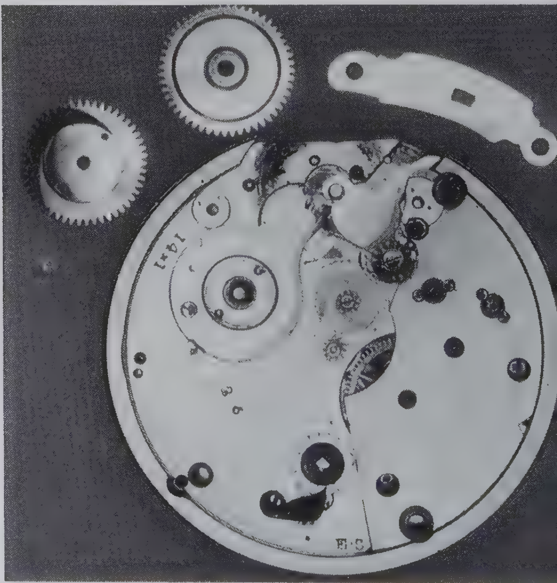

a


b


DOWN UP
24 18 12 6
JOHN BENNETT
65 & 64 CHEAPSIDE
LONDON 15425
60 10 20 30 40 50
c


Jn. Bennett 65&
Cheapside
London
No. 15425
d

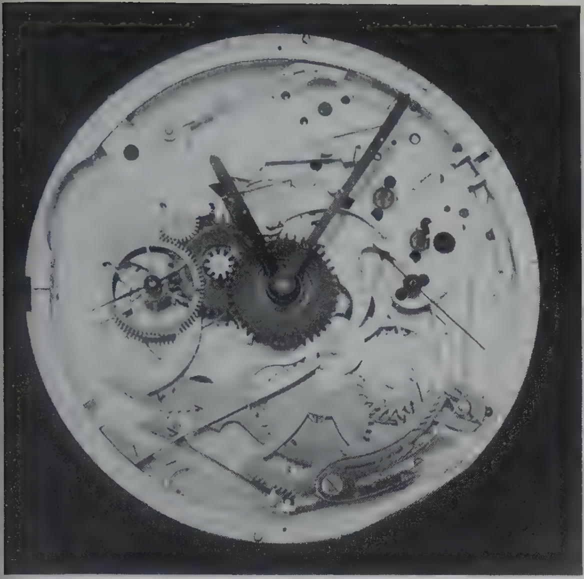

e



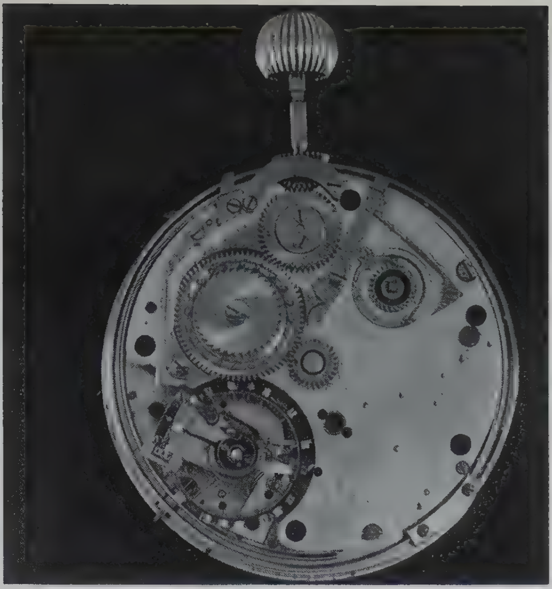
f

Plate 69

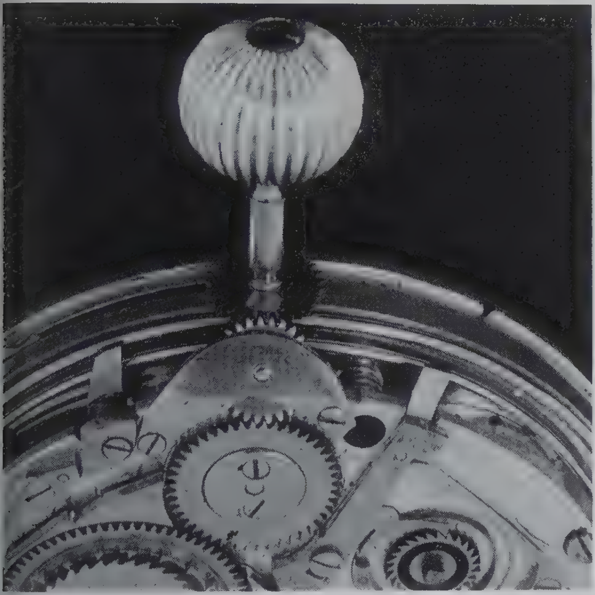
a. Cat. no. 107.
The dial is missing.
b. Cat. no. 107.
c. Cat. no. 107.
d. Cat. no. 107.
e. Cat. no. 107.
f. Cat. no. 107.



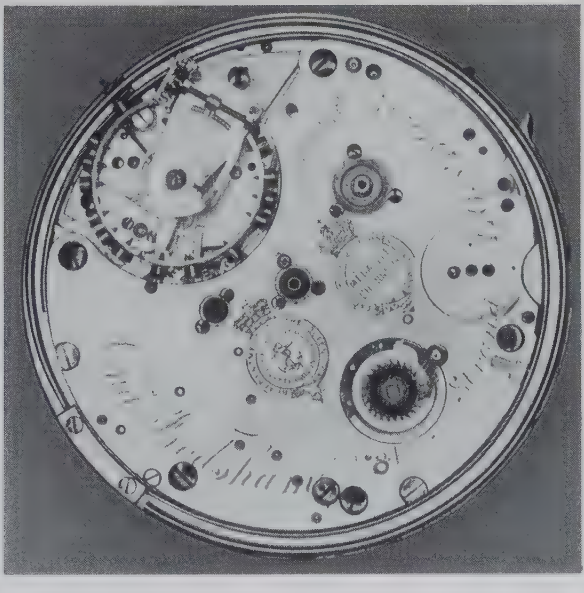
a



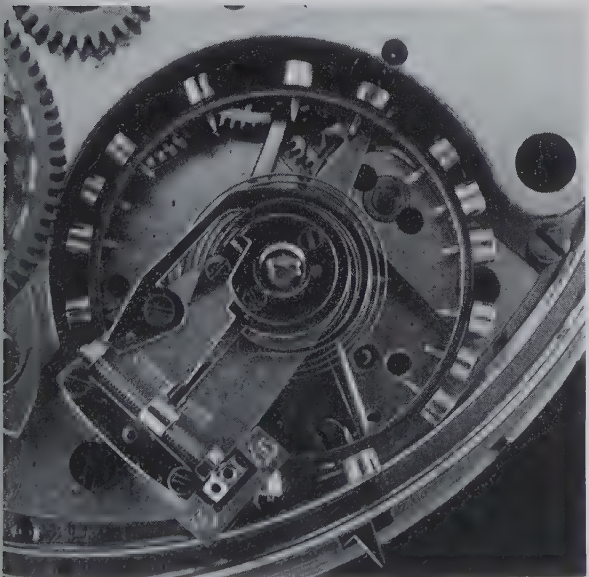
b



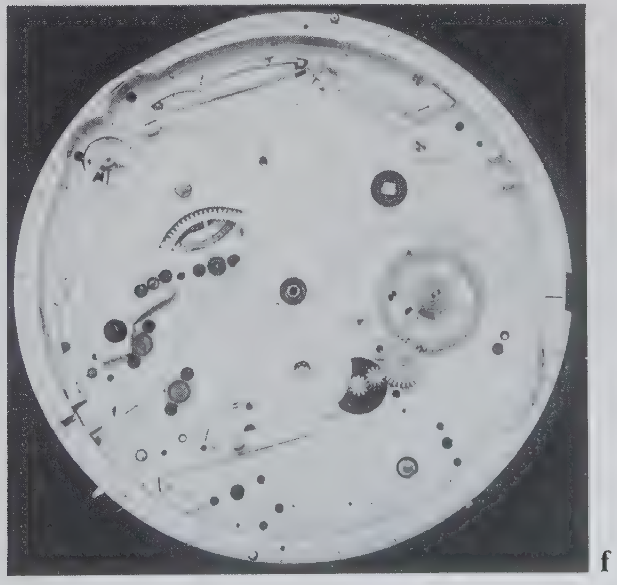
c



d



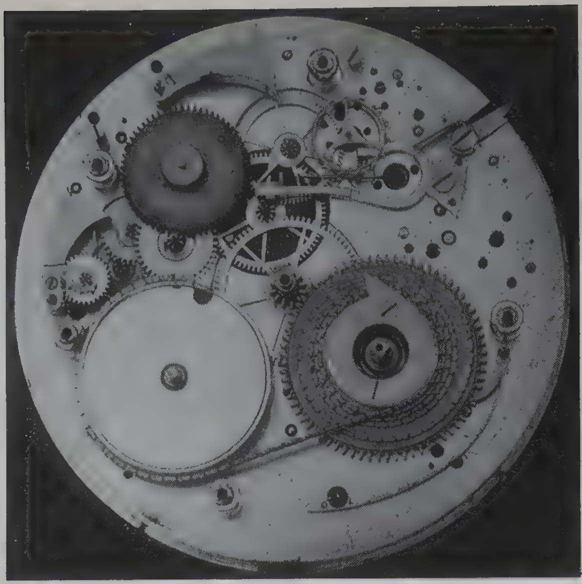
e

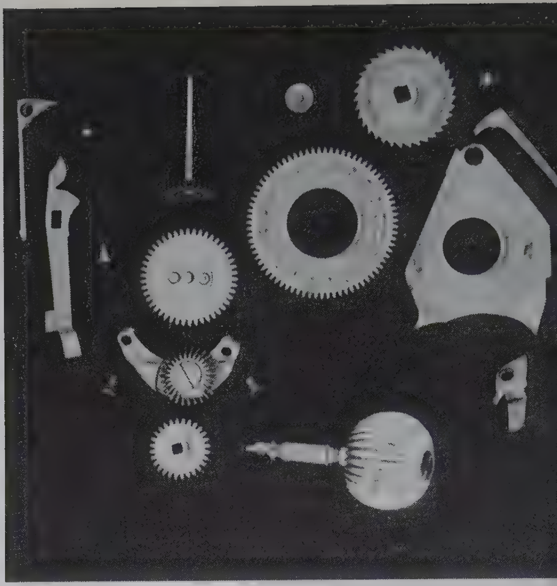


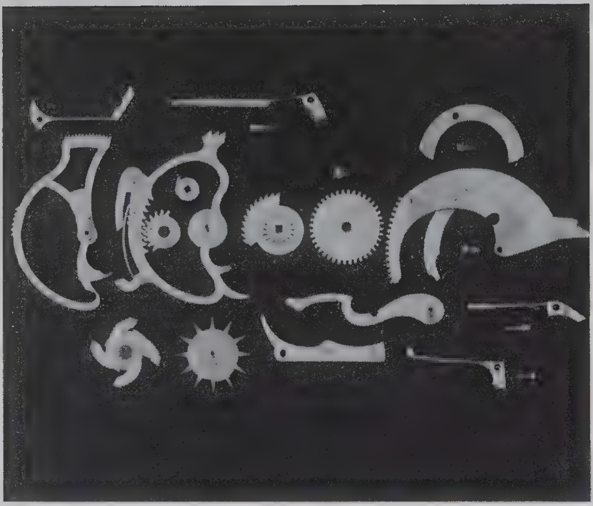
f

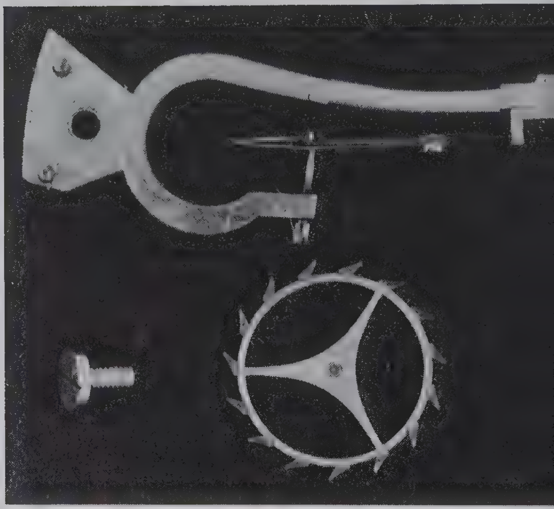
Plate 70

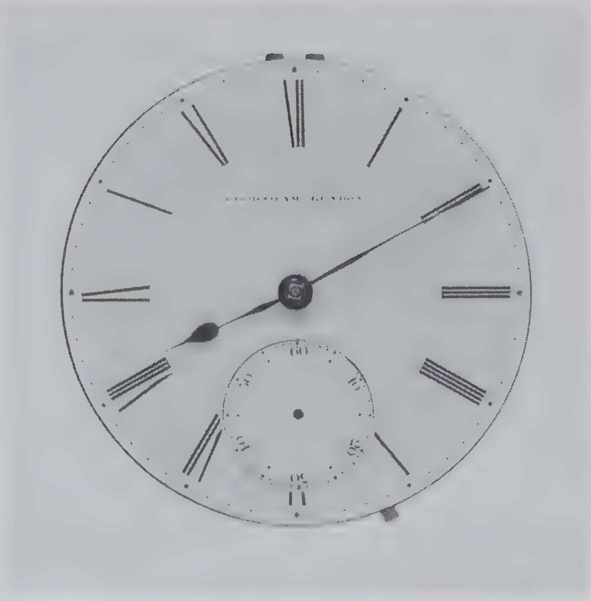
a. Cat. no. 107.
b. Cat. no. 107, the winding and hand-set work.
c. Cat. no. 107.
d. Cat. no. 107. *See cat. no. 114 for a similar design.*
e. Cat. no. 108.
f. Cat. no. 108.


a


b


c


d


e

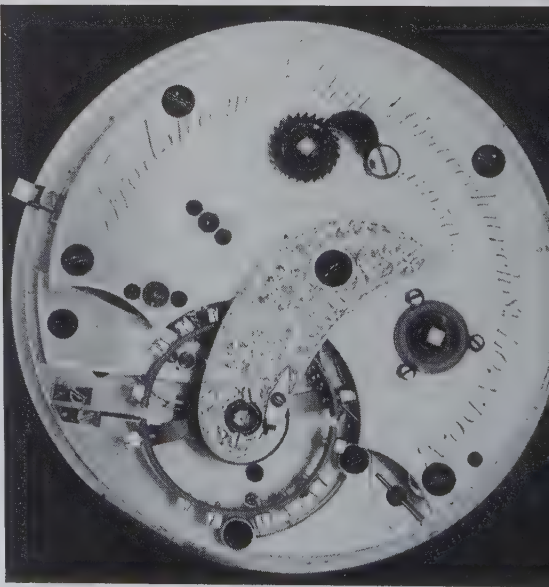
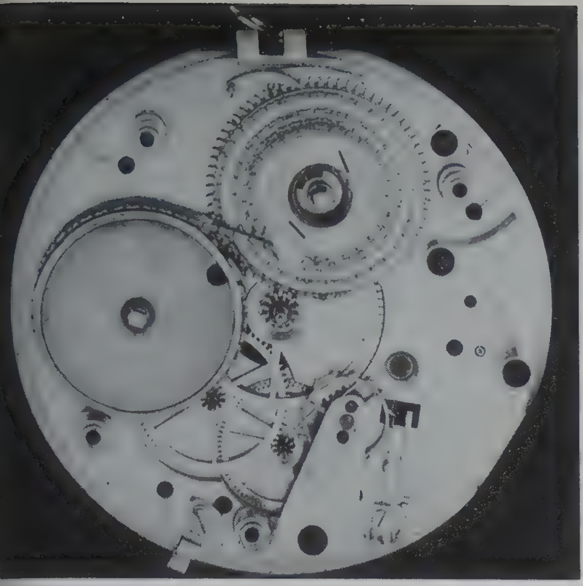
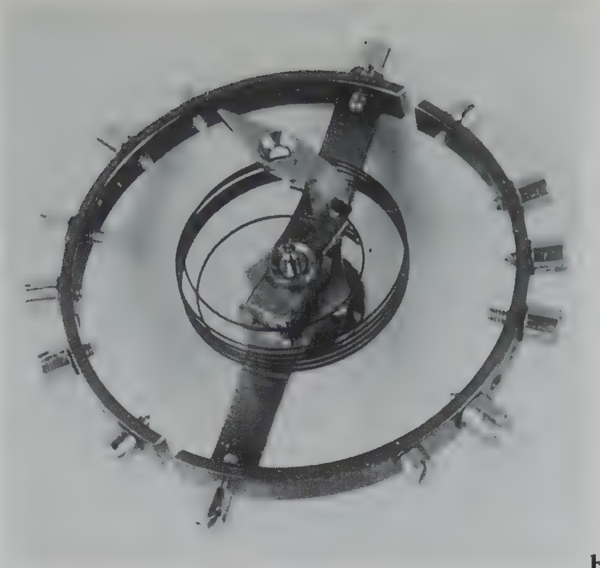
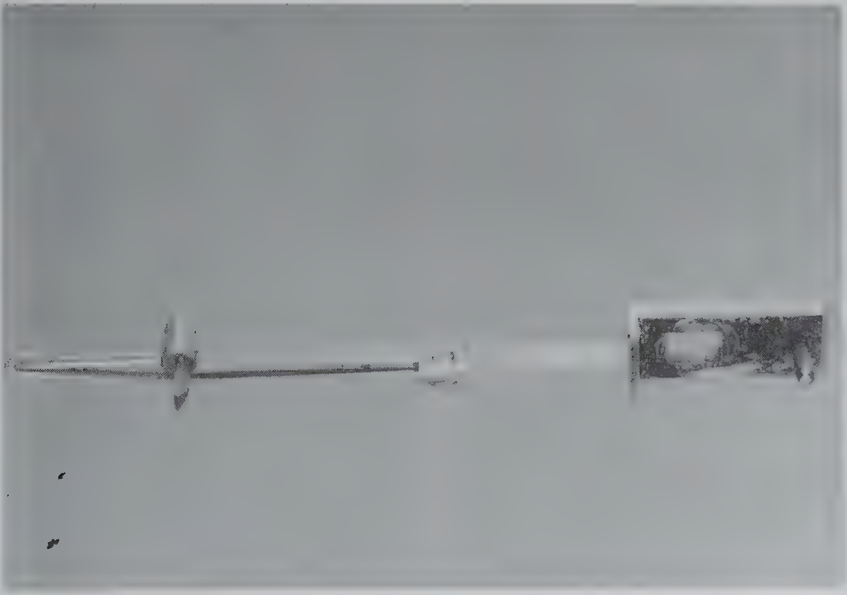

f

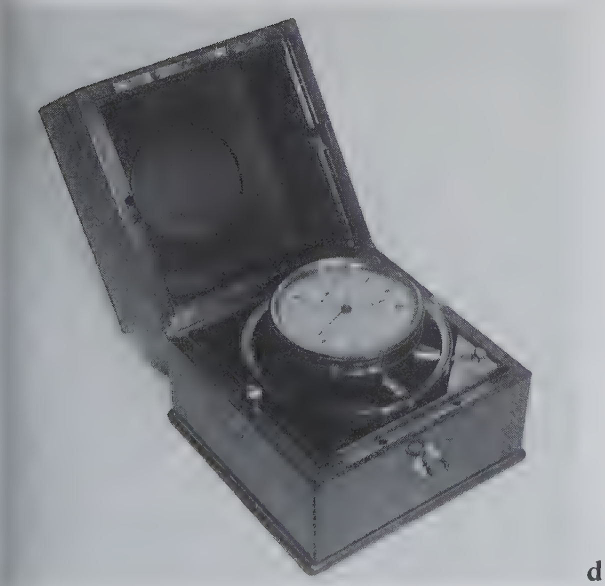
Plate 71

a. Cat. no. 108.
b. Cat. no. 108.
c. Cat. no. 108.
d. Cat. no. 109.
e. Cat. no. 109.


a


b


c


d

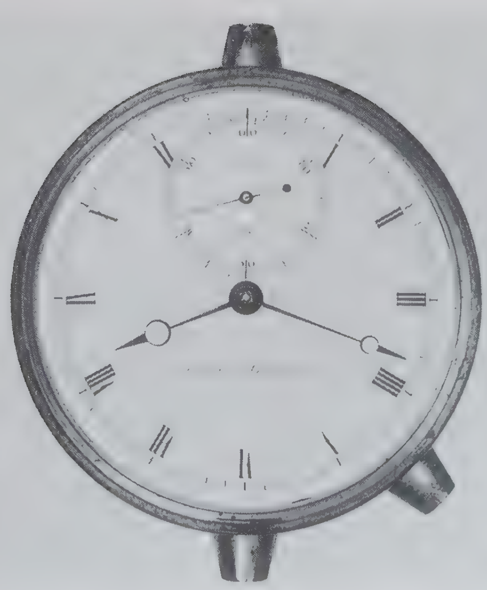
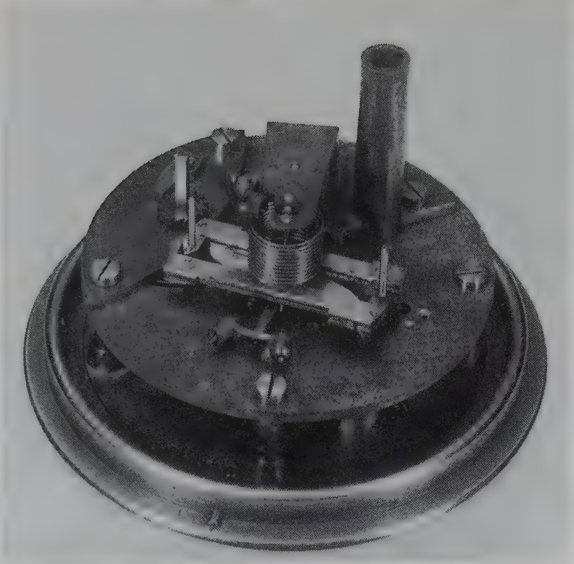
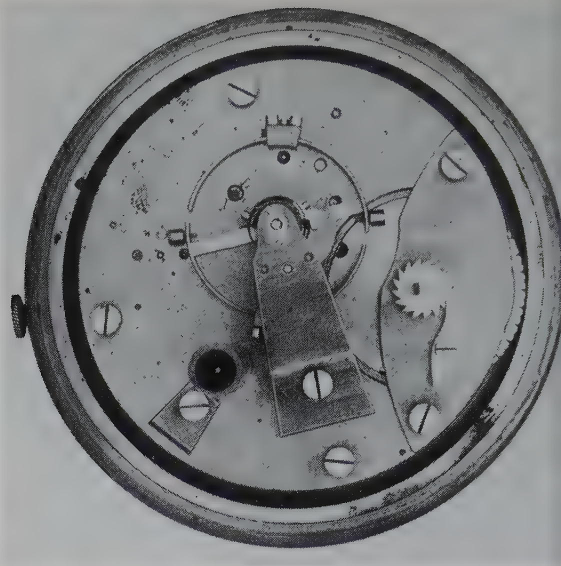
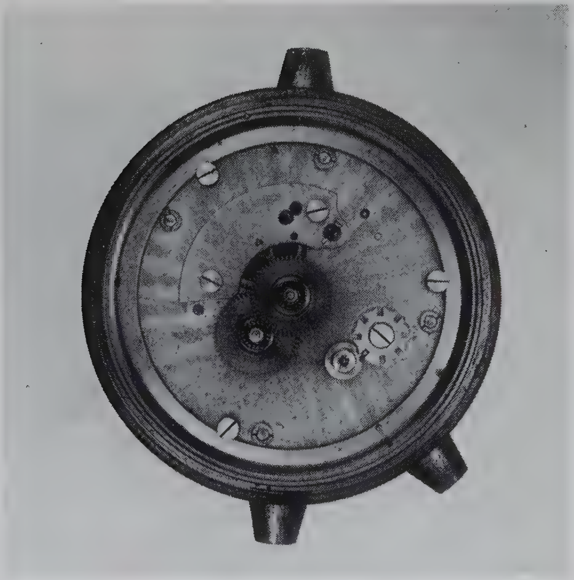

e

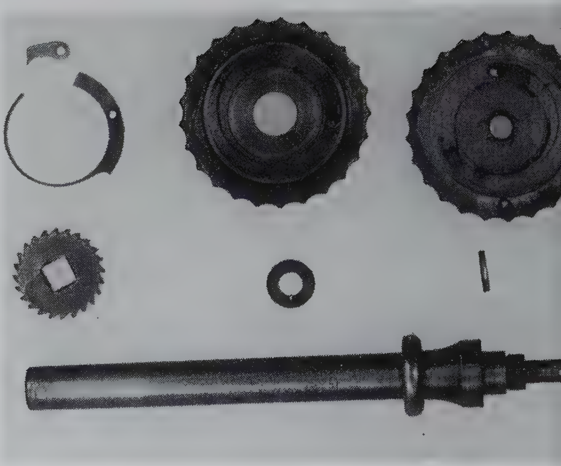
Plate 72

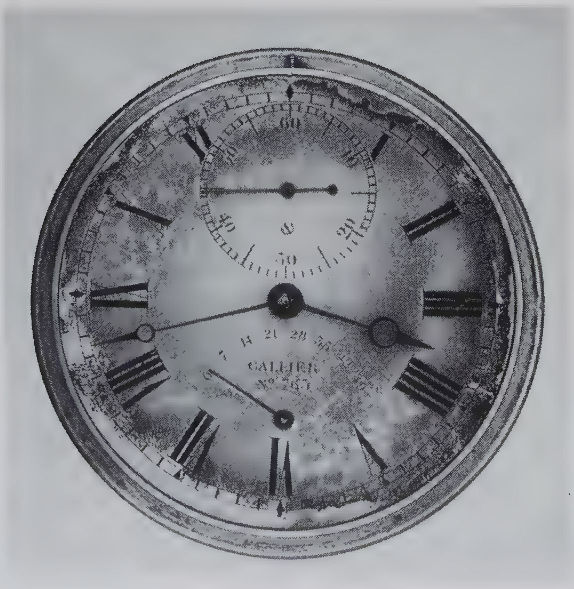
a. Cat. no. 109.
b. Cat. no. 109.
c. Cat. no. 109.
d. Cat. no. 109, the key.
e. Cat. no. 110.
f. Cat. no. 110.


a


b


c


d


60
40
20
50
14 21 28
CALLIER
e

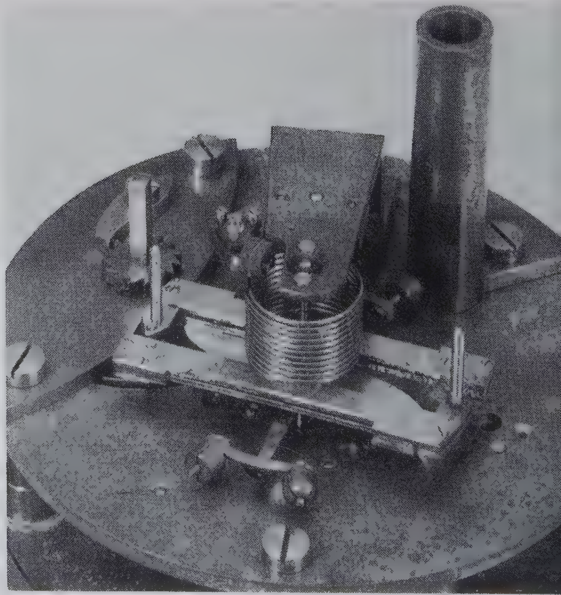
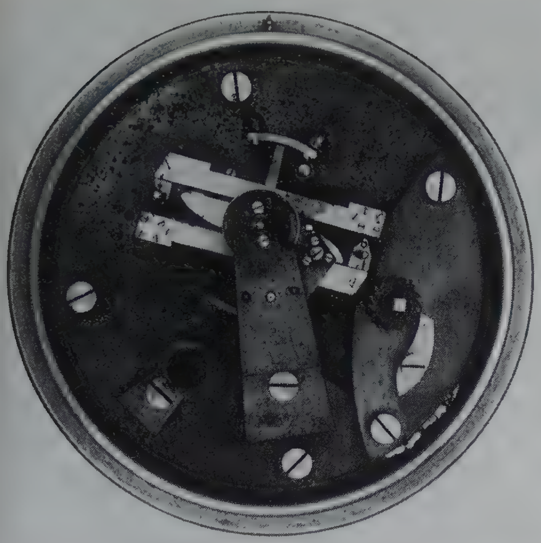
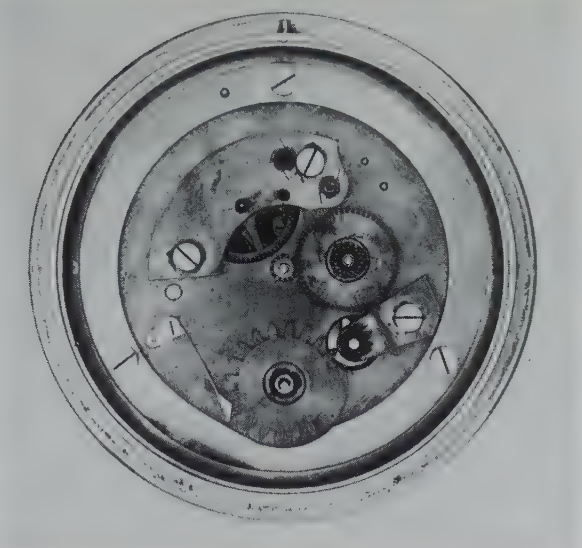
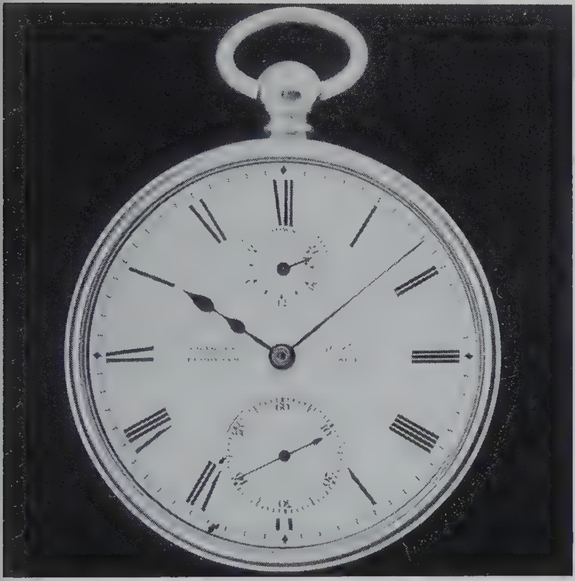

f

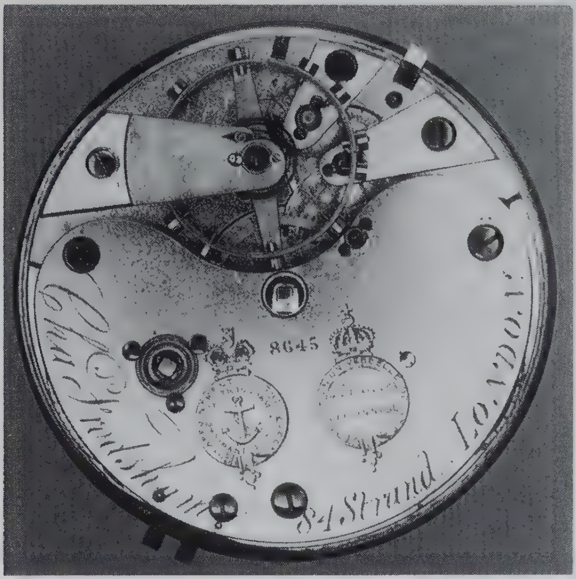
Plate 73

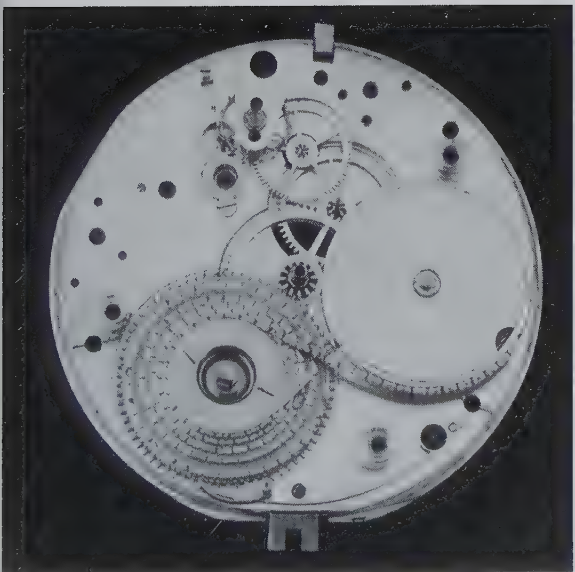
a. Cat. no. 110.
b. Cat. no. 110.
c. Cat. no. 111.
d. Cat. no. 111.
e. Cat. no. 111. Note the reversed fusee.
f. Cat. no. 111.


a


b


c


8645
Chas Frodsham
84 Strand LONDON
d


e

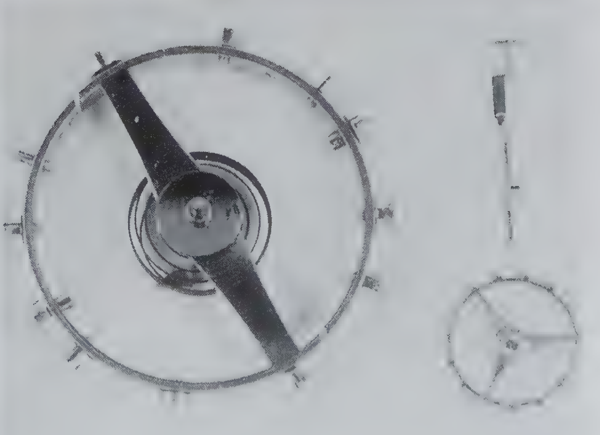
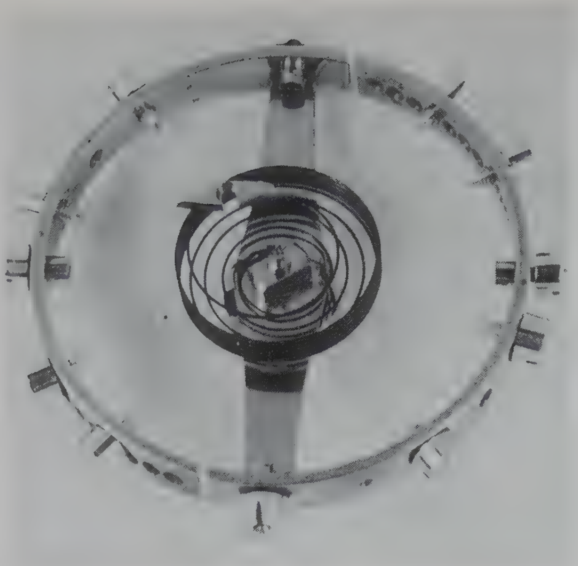
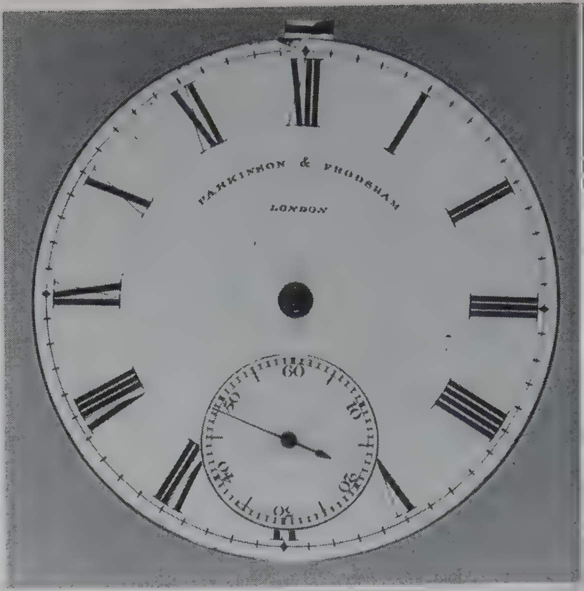

f

Plate 74

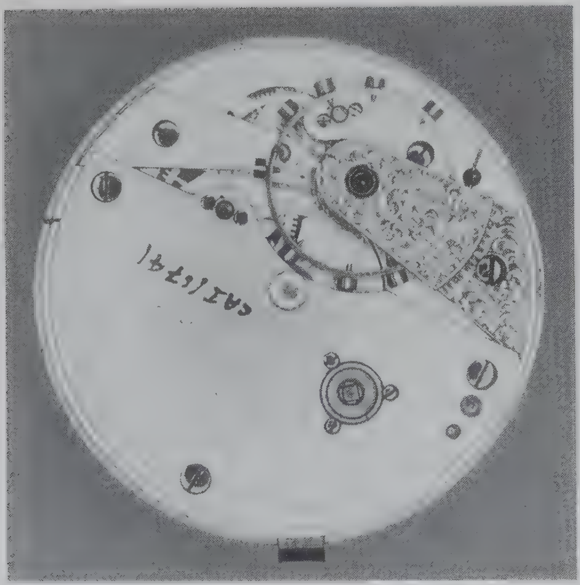
a. Cat. no. 111.
b. Cat. no. 112.
c. Cat. no. 112.
d. Cat. no. 112.
e. Cat. no. 113.
f. Cat. no. 113.



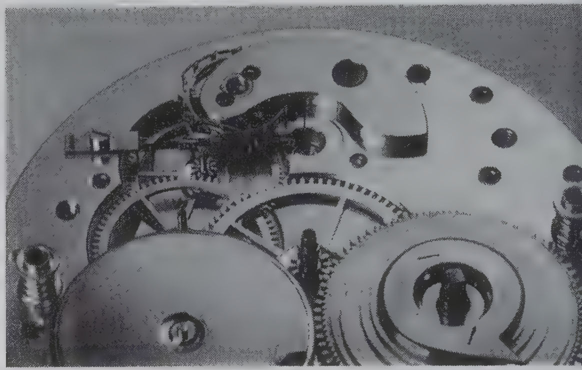
a


PARKINSON & FRODSHAM
LONDON
60

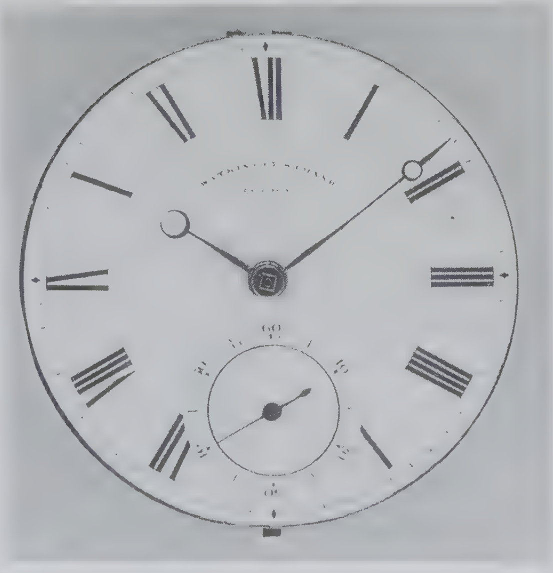
b



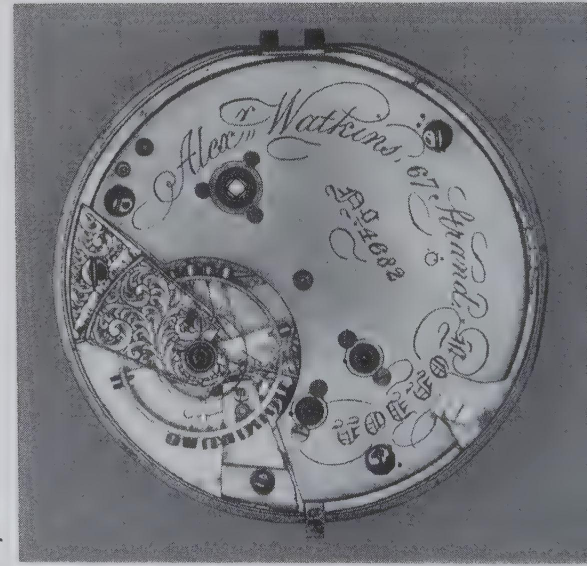
c



d



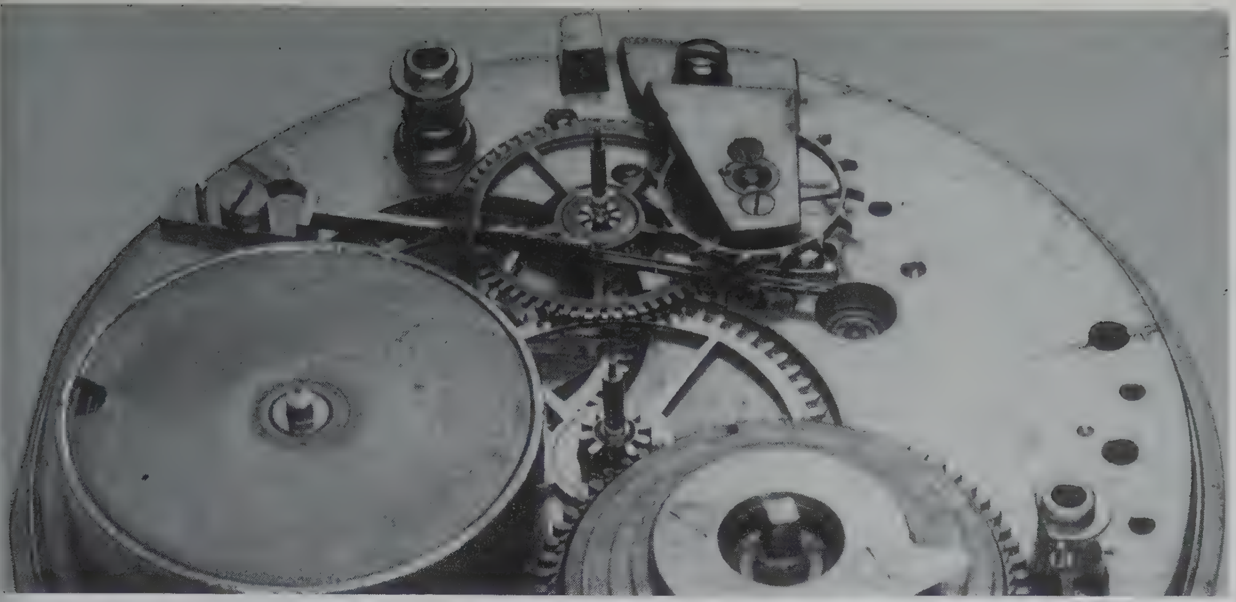
e


Alexr Watkins, 67 Strand

f

Plate 75

a. Cat. no. 113.
b. Cat. no. 114.
c. Cat. no. 114.
d. Cat. no. 114.
See cat. no. 107 for a similar design of detent support.


a

b

WEBSTER & SON
CAI/1254
c

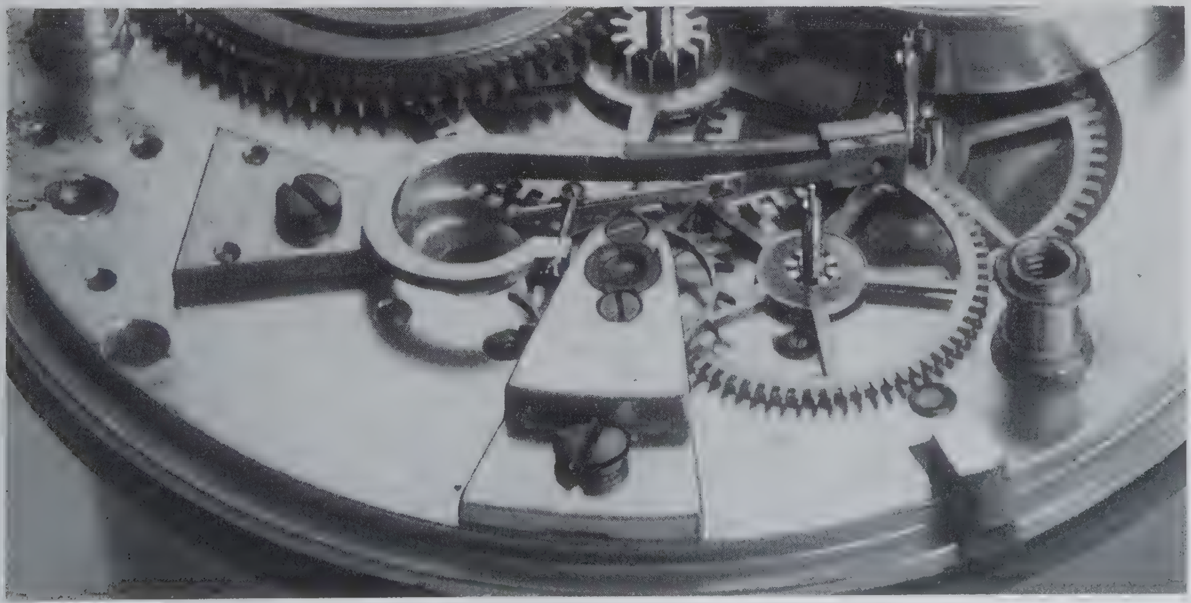
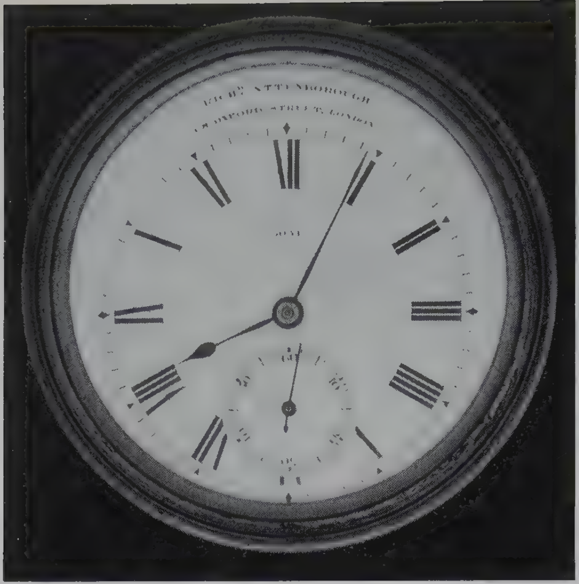
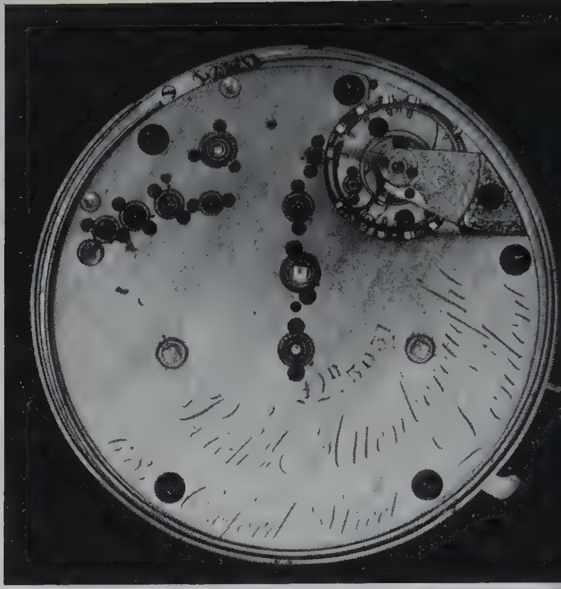

d

Plate 76

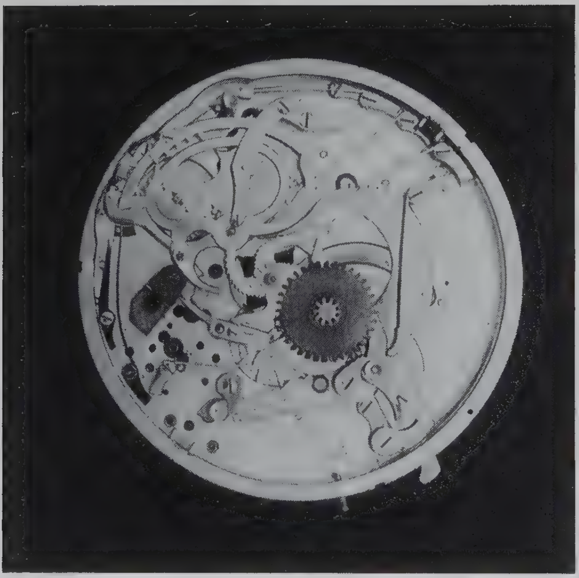
- **a.** Cat. no. 115.
- **b.** Cat. no. 115.
- **c.** Cat. no. 115.
- **d.** Cat. no. 115.
- **e.** Cat. no. 116.
- **f.** Cat. no. 116.


OXFORD STREET, LONDON

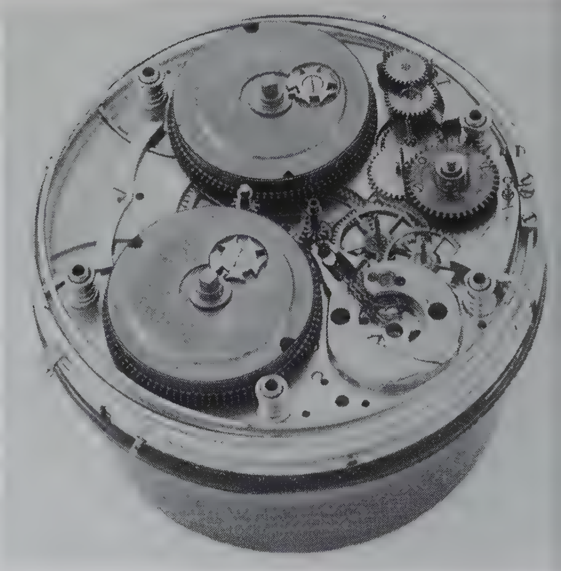
a


Rich.d Attenborough
Oxford Street

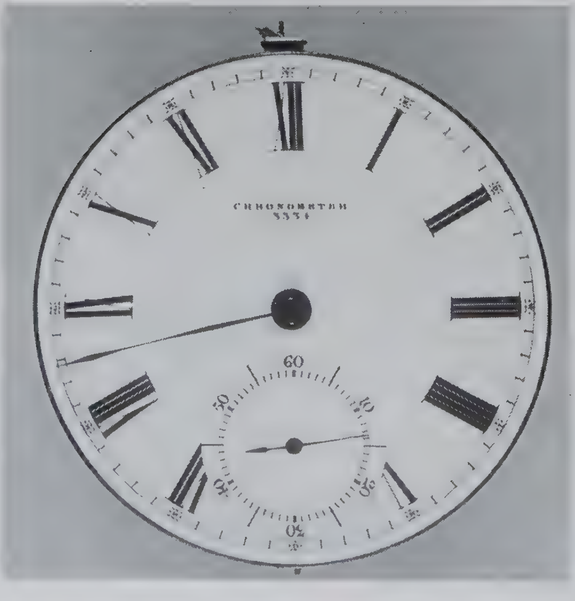
b



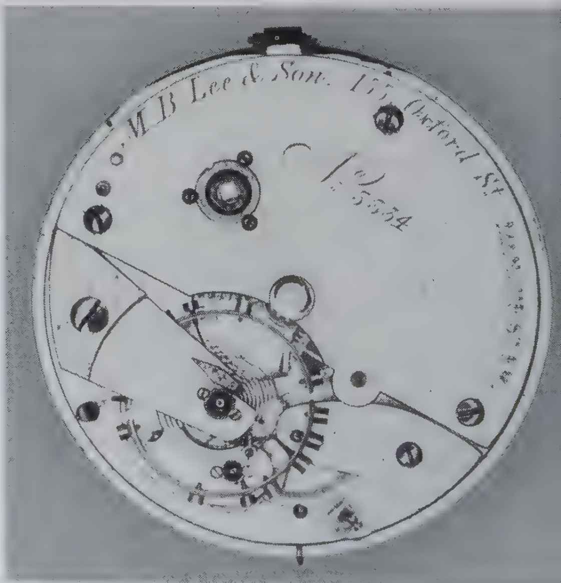
c



d


CHRONOMETER
5534
60
10
20
30
40
50

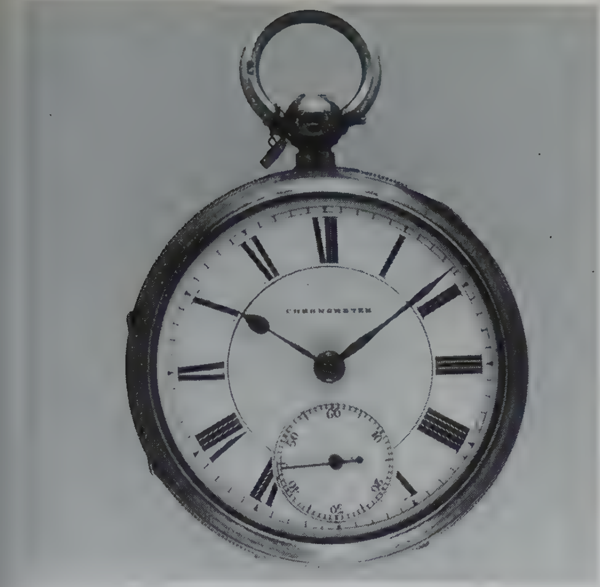
e


M.B Lee & Son. 177 Oxford St
No 5534

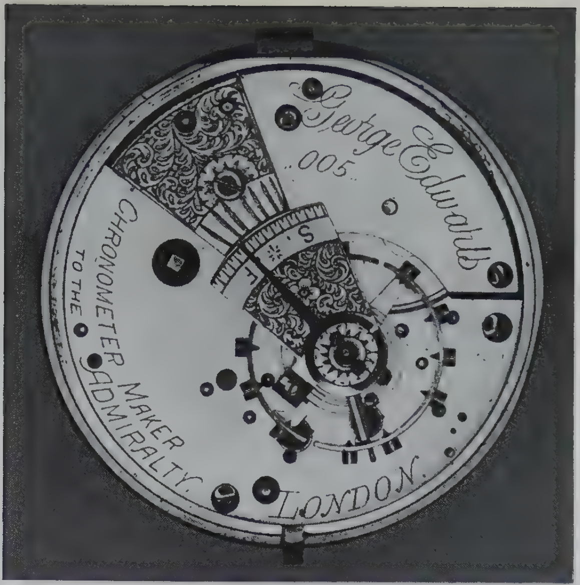
f

Plate 77

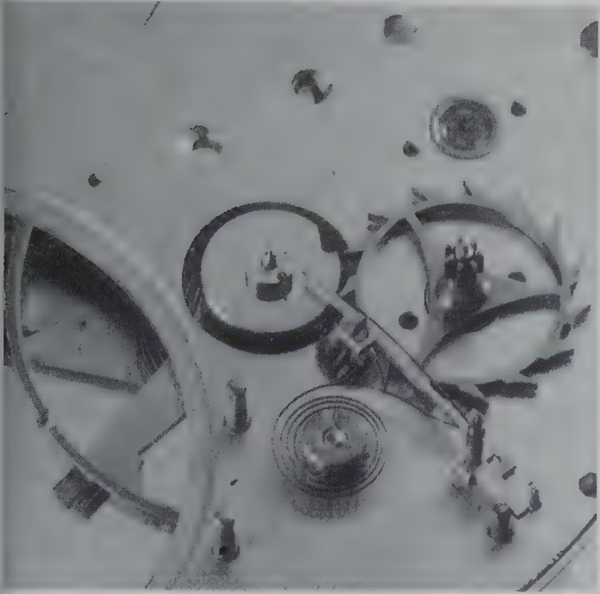
a. Cat. no. 117.
b. Cat. no. 117.
c. Cat. no. 117. Note the spiral detent return spring.
d. Cat. no. 117.
e. Cat. no. 117A.
f. Cat. no. 117A.


CHRONOMETER

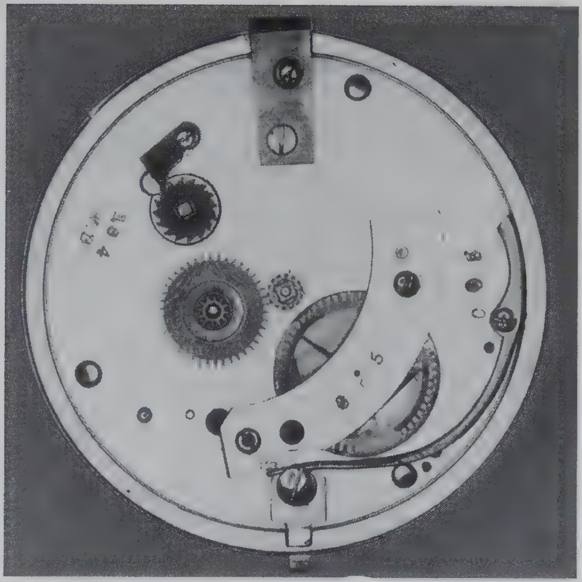
a


George Edwards
005
CHRONOMETER MAKER
TO THE ADMIRALTY
LONDON

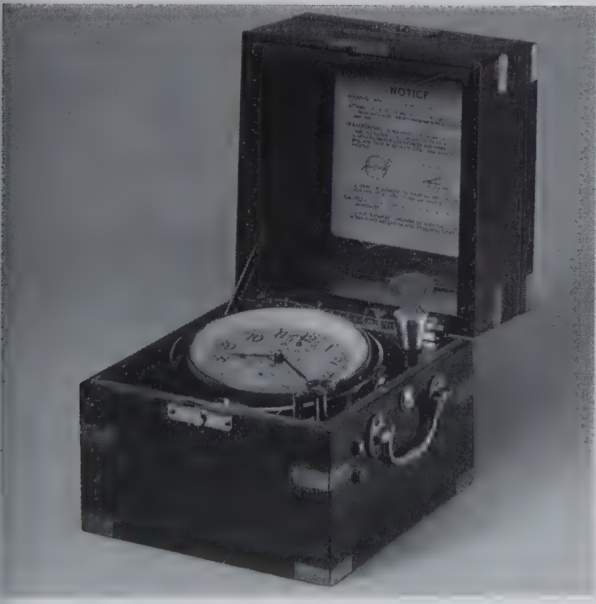
b



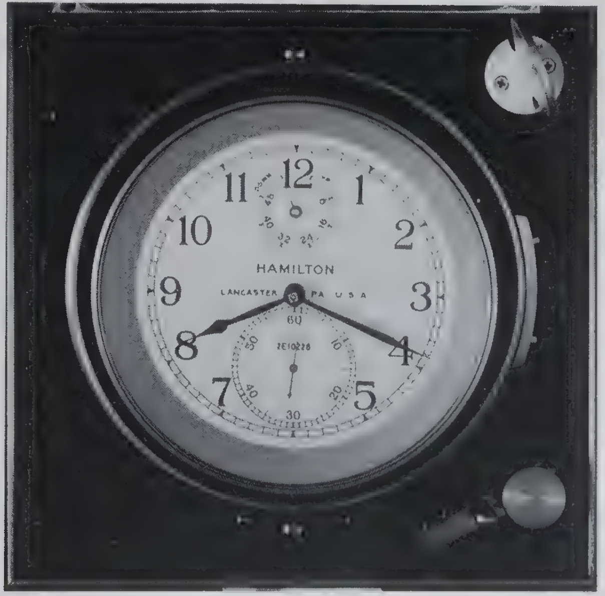
c



d



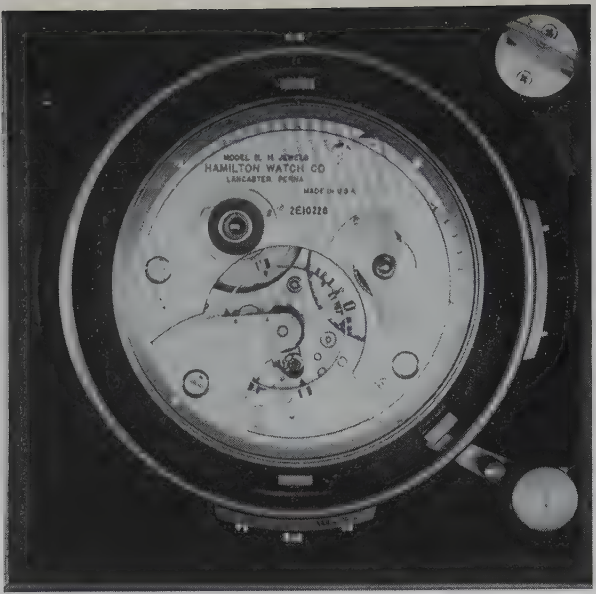
e


HAMILTON
LANCASTER PA U S A
2E10228

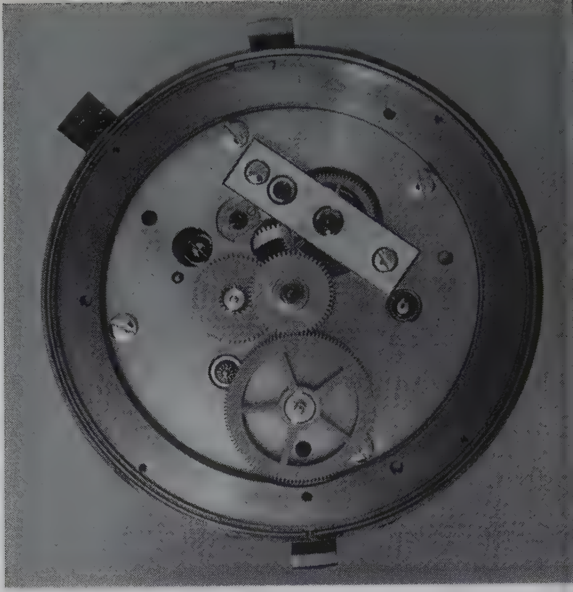
f

Plate 78

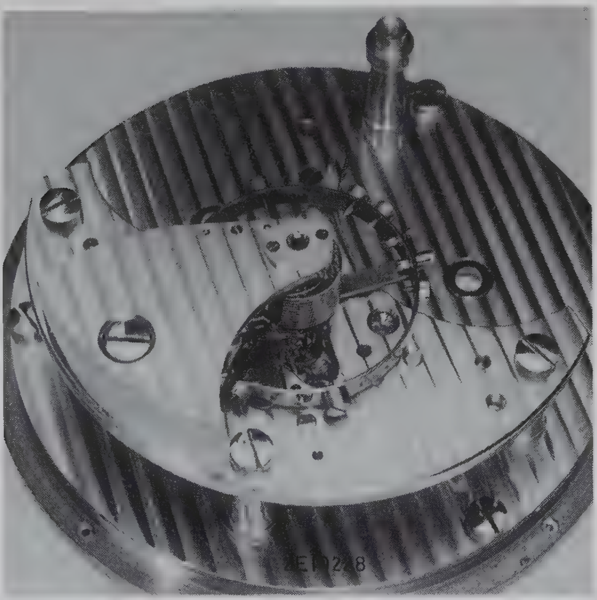
a. Cat. no. 117A.
b. Cat. no. 117A.
c. Cat. no. 117A.
d. Cat. no. 117A.
e. Cat. no. 117A.
f. Cat. no. 117A.


MODEL 21 21 JEWELS
HAMILTON WATCH CO
LANCASTER PENNA
MADE IN U.S.A.
2E10228

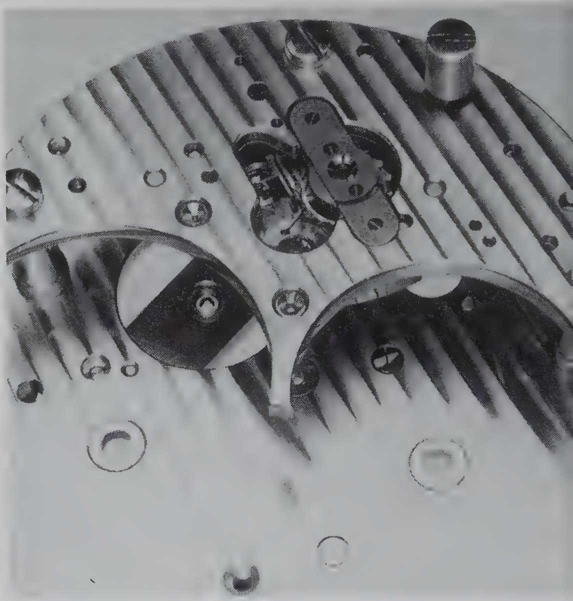
a



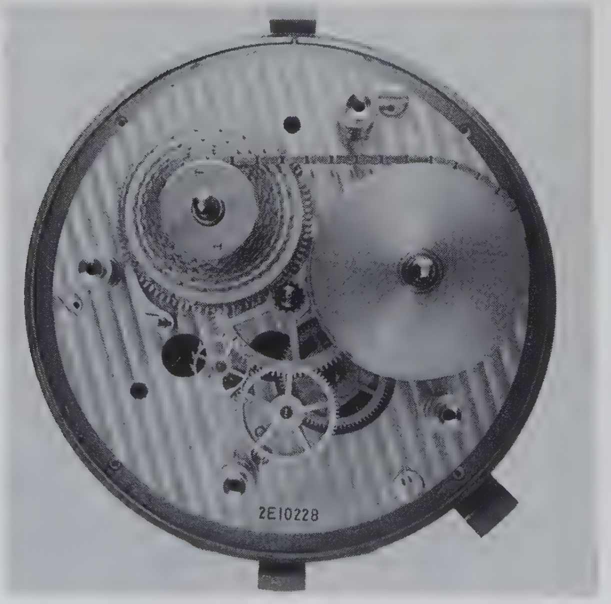
b



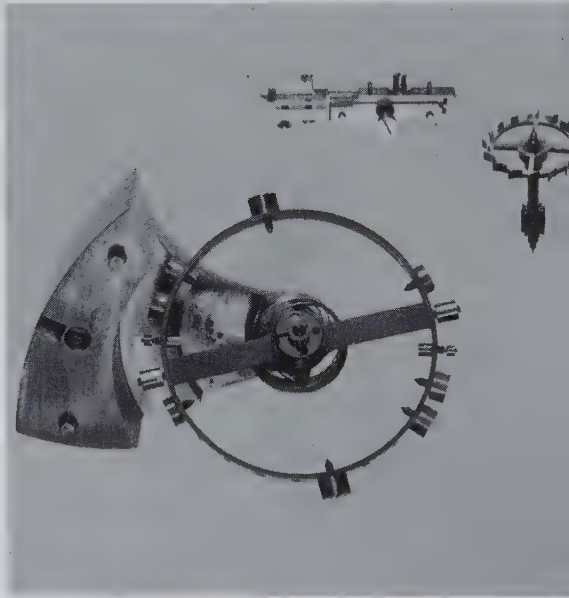
c



d



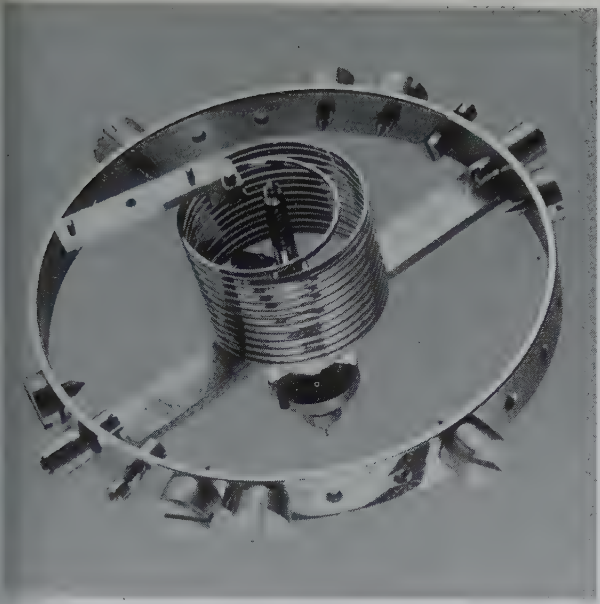
e



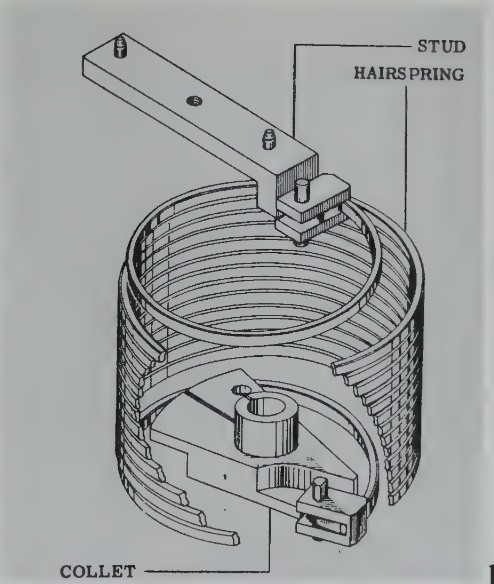
f

Plate 79

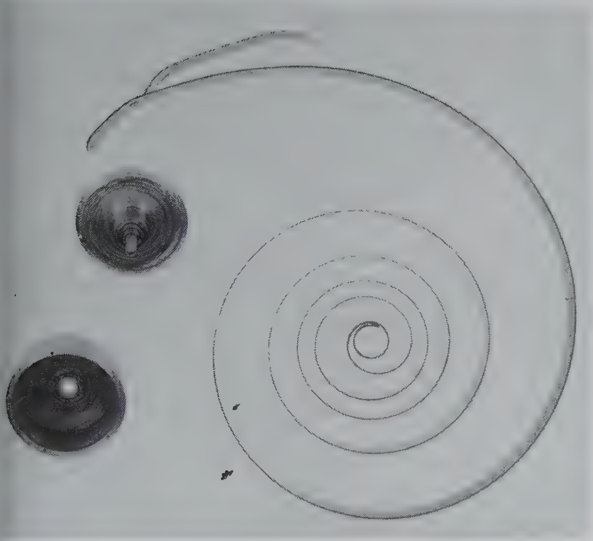
a. Cat. no. 117A.
b. Cat. no. 117A, showing the clamps for the spring ends.
c. Cat. no. 117A. Note the brace.
d. Cat. no. 117A.
e. Cat. no. 118.
f. Cat. no. 118.



a



b



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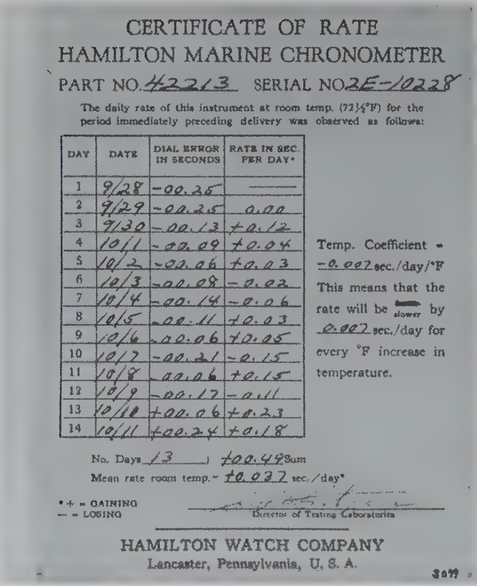


CERTIFICATE OF RATE
HAMILTON MARINE CHRONOMETER

PART NO. 42213 SERIAL NO. 2E-10228

The daily rate of this instrument at room temp. (72½°F) for the period immediately preceding delivery was observed as follows:

DAY	DATE	DIAL ERROR IN SECONDS	RATE IN SEC. PER DAY*
1	9/28	-00.25	——
2	9/29	-00.25	0.00
3	9/30	-00.13	+0.12
4	10/1	-00.09	+0.04
5	10/2	-00.06	+0.03
6	10/3	-00.08	-0.02
7	10/4	-00.14	-0.06
8	10/5	-00.11	+0.03
9	10/6	-00.06	+0.05
10	10/7	-00.21	-0.15
11	10/8	-00.06	+0.15
12	10/9	-00.17	-0.11
13	10/10	+00.06	+0.23
14	10/11	+00.24	+0.18

Temp. Coefficient = -0.002 sec./day/°F
This means that the rate will be slower by 0.002 sec./day for every °F increase in temperature.

No. Days 13 ; +00.49 Sum
Mean rate room temp. = +0.037 sec./day*

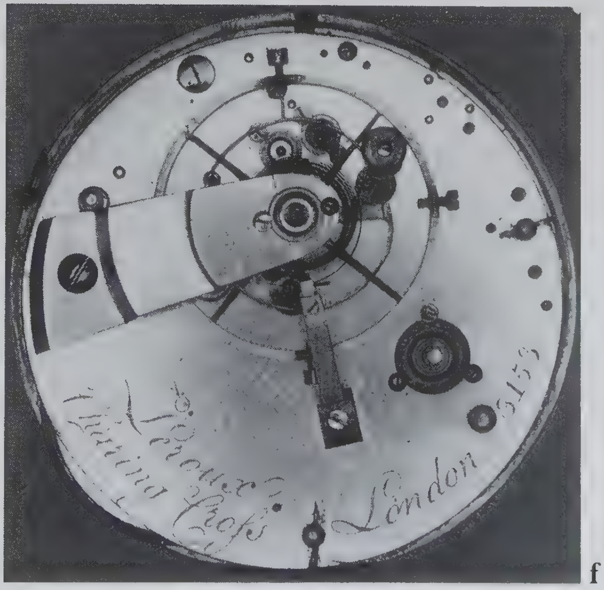
* + = GAINING
— = LOSING

Director of Testing Laboratories

HAMILTON WATCH COMPANY
Lancaster, Pennsylvania, U. S. A.

d

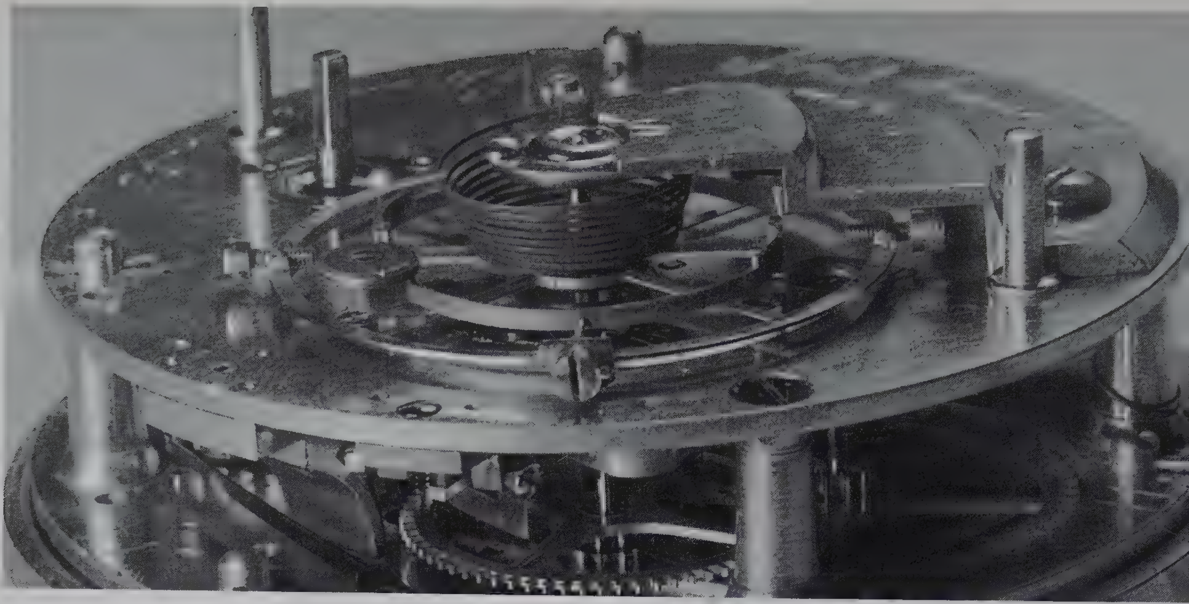
e

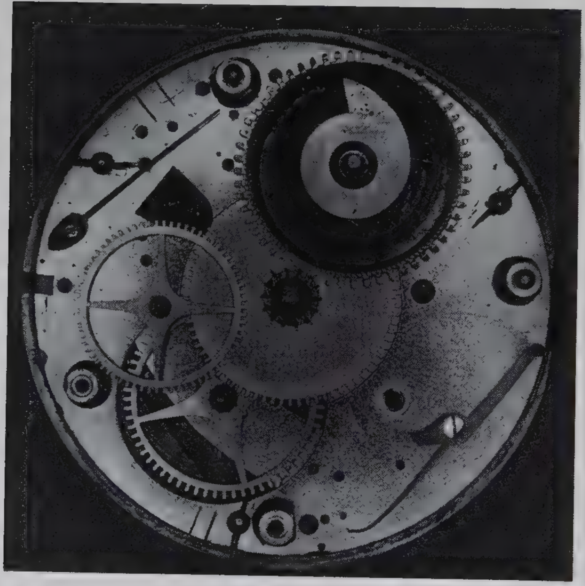


f

Plate 80

- **a.** Cat. no. 118.
- **b.** Cat. no. 118.
- **c.** Cat. no. 118.
- **d.** Cat. no. 118.
- **e.** Cat. no. 118.


a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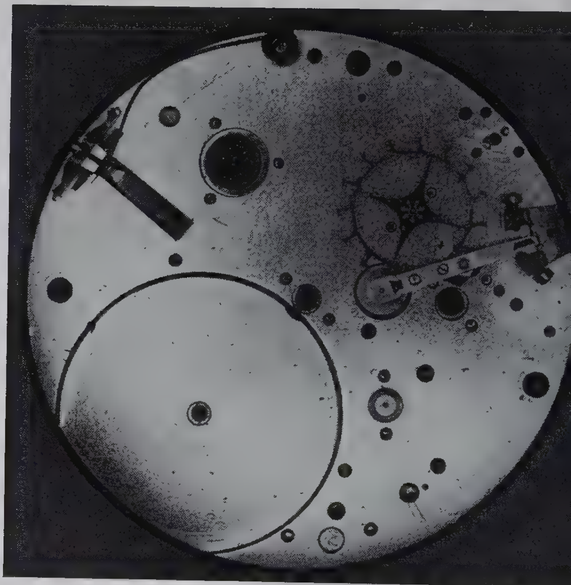
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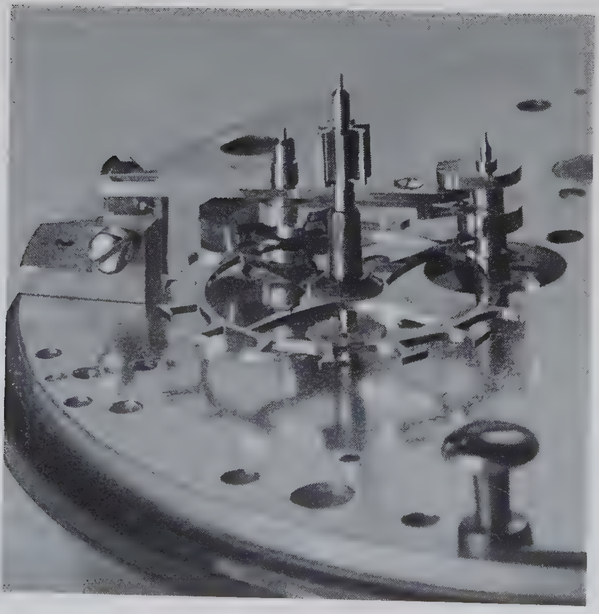

d

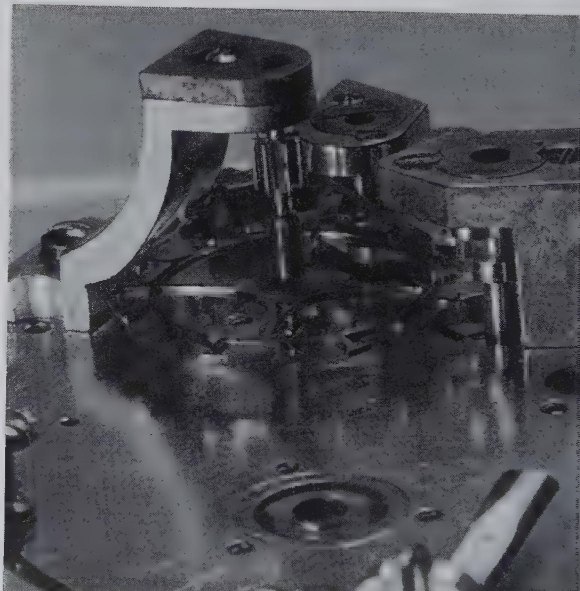
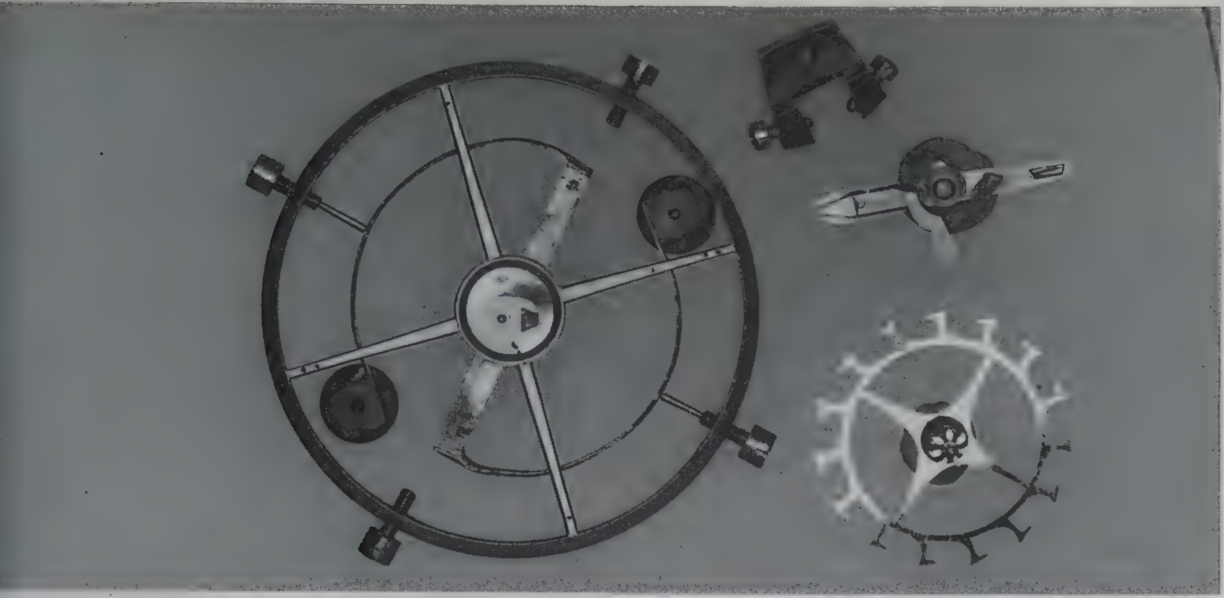
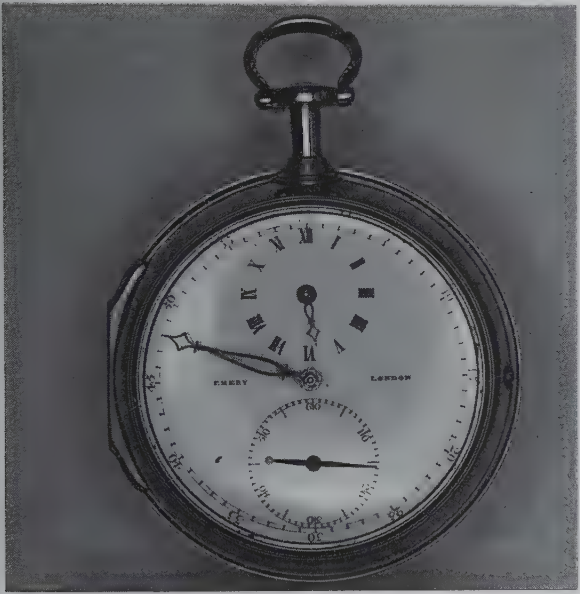

e

Plate 81

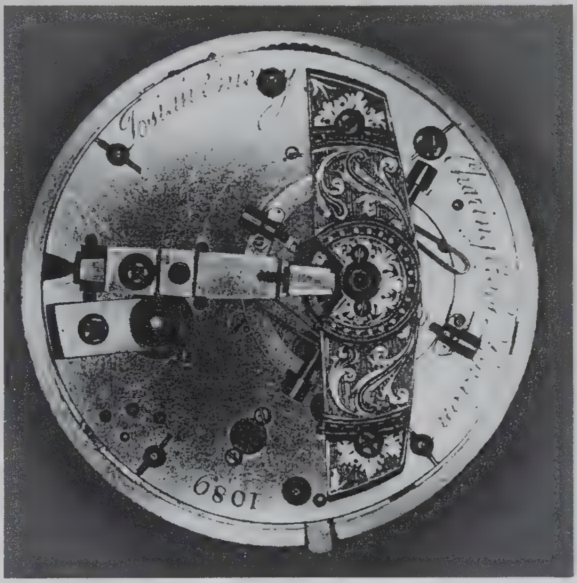
a. Cat. no. 118.
b. Cat. no. 119.
c. Cat. no. 119.
d. Cat. no. 119.
e. Cat. no. 119.



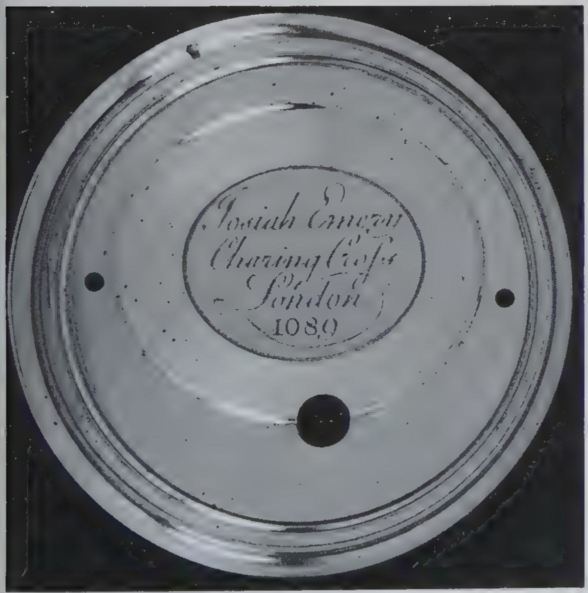
a


EMERY
LONDON

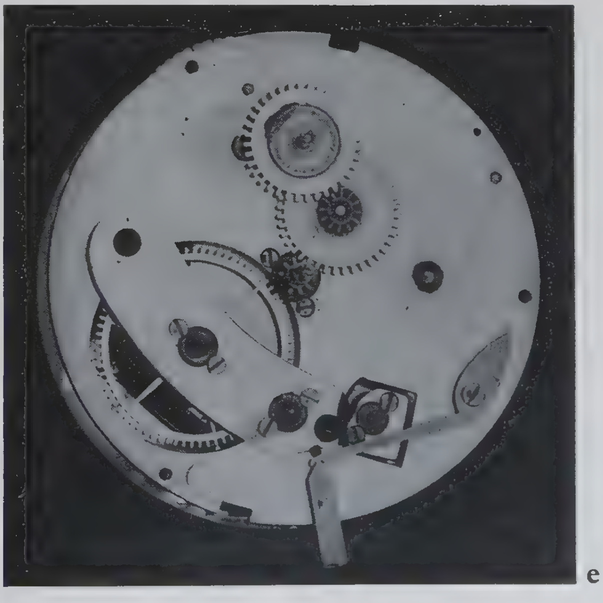
b


Josiah Emery
Charing Cross London
1089

c


Josiah Emery
Charing Cross
London
1089

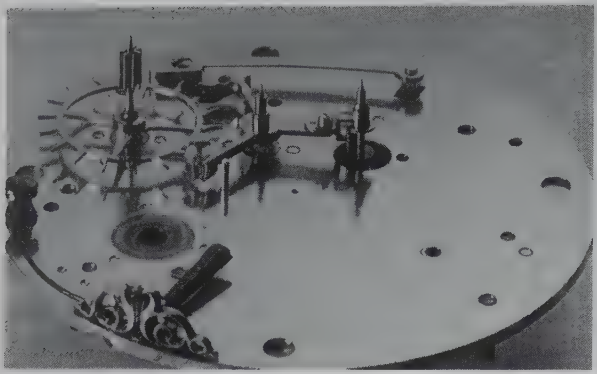
d

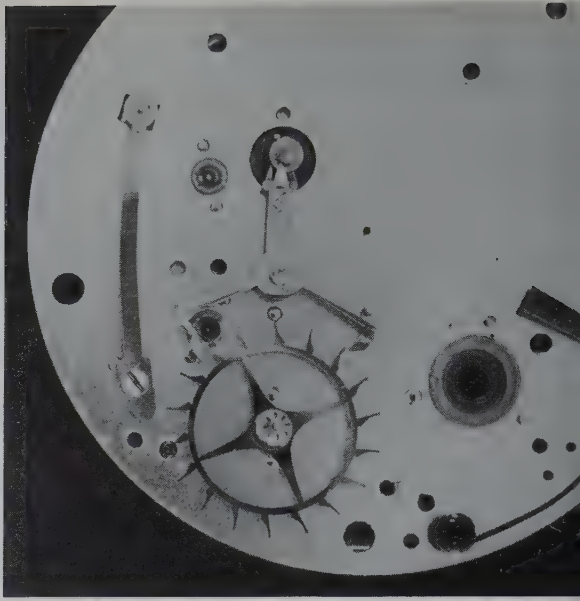


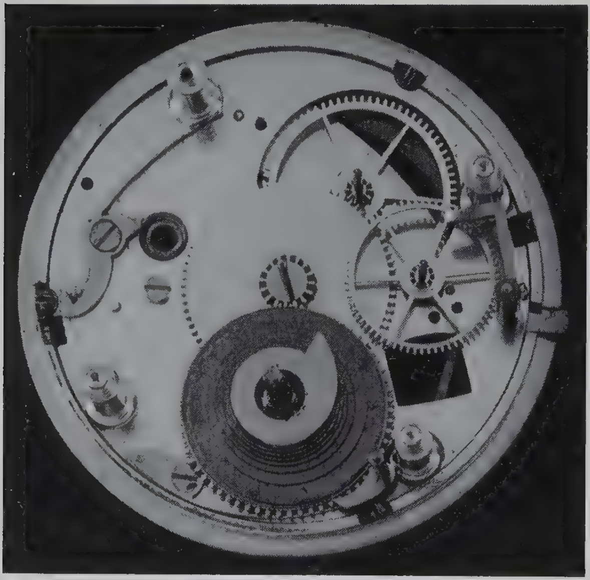
e

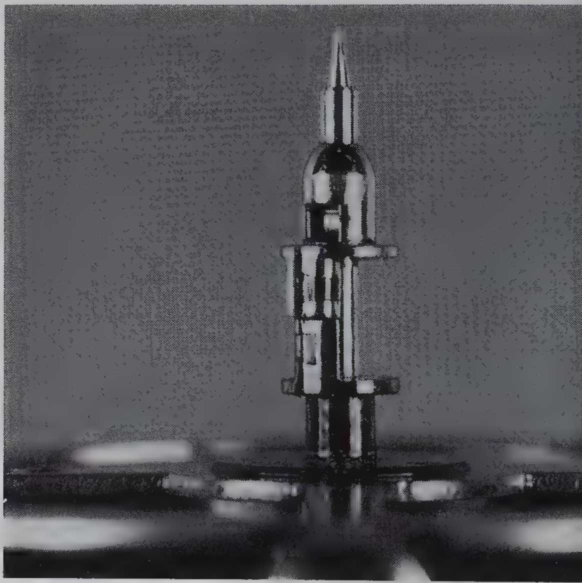
Plate 82

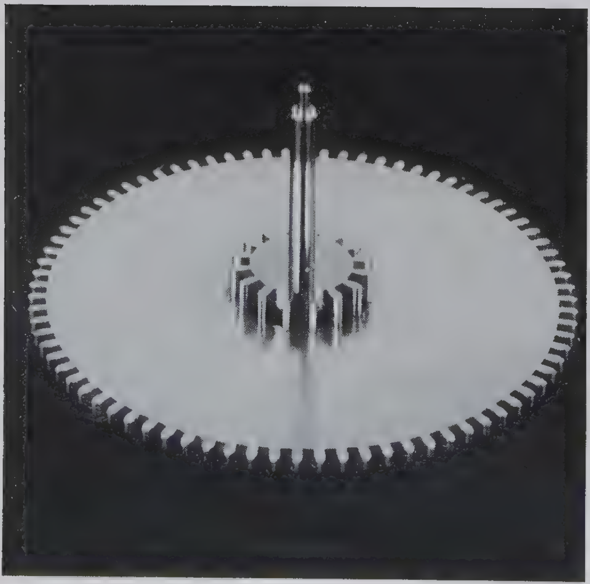
a. Cat. no. 119.
b. Cat. no. 119.
c. Cat. no. 119.
d. Cat. no. 119.
e. Cat. no. 119.
f. Cat. no. 119.

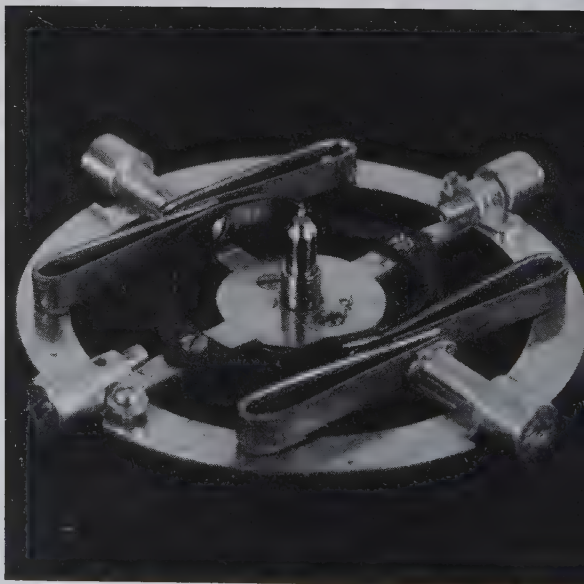

a

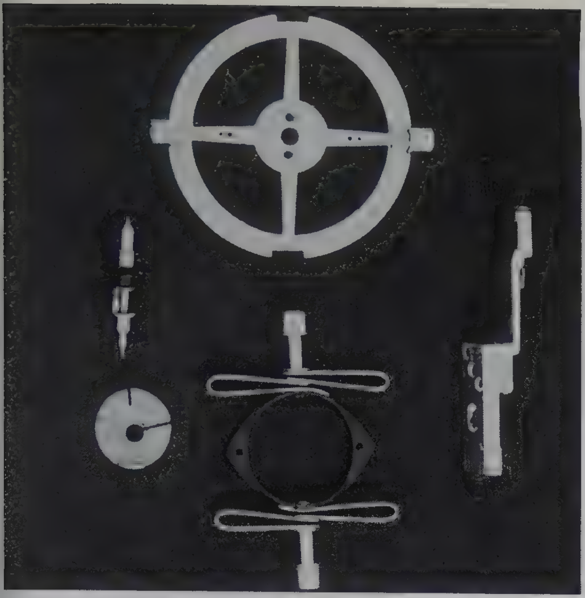

b


c

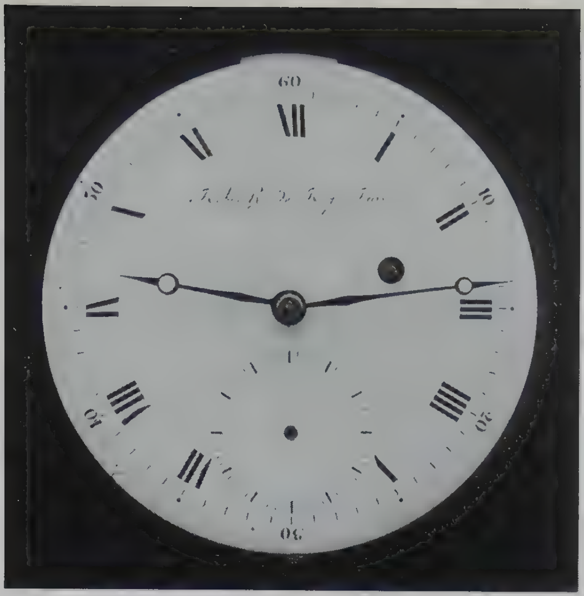

d


e


f



a


60
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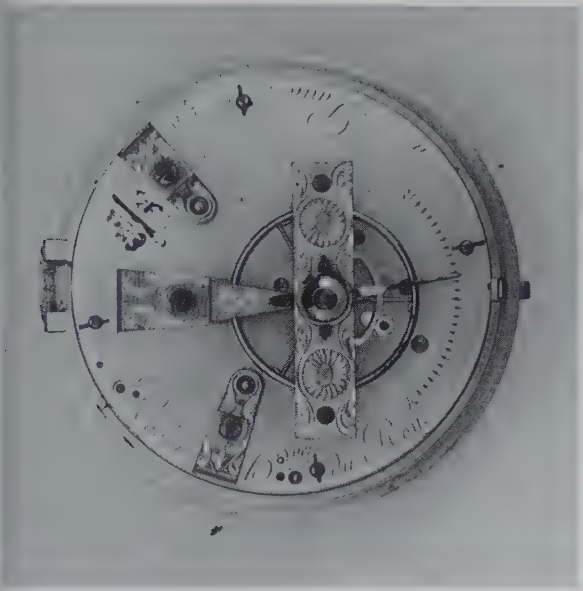
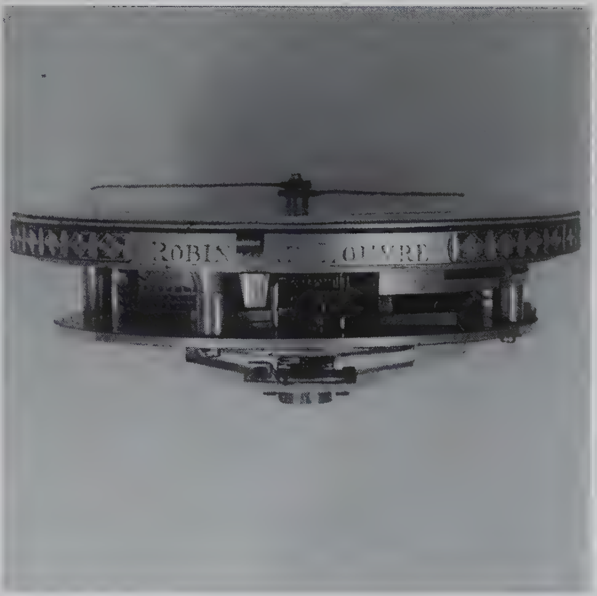
b



c



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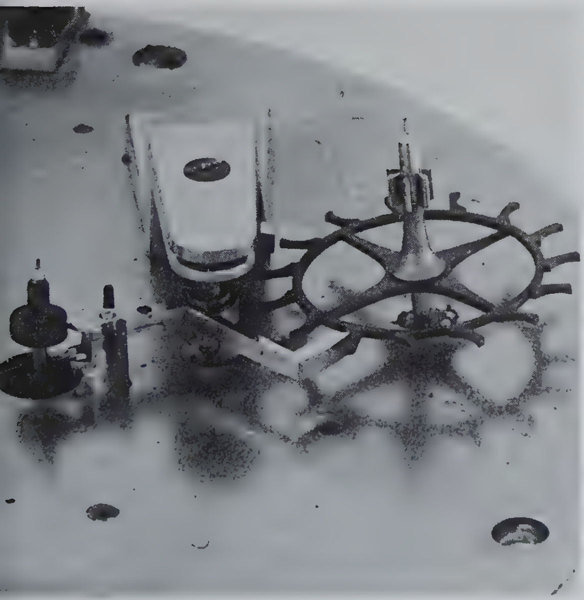
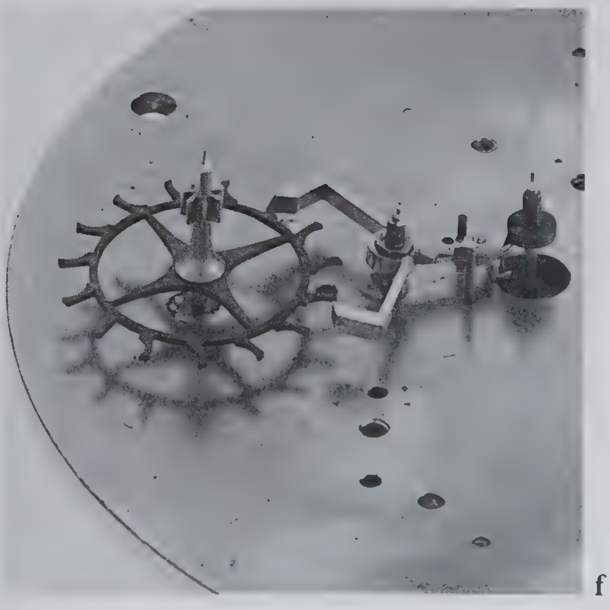


e



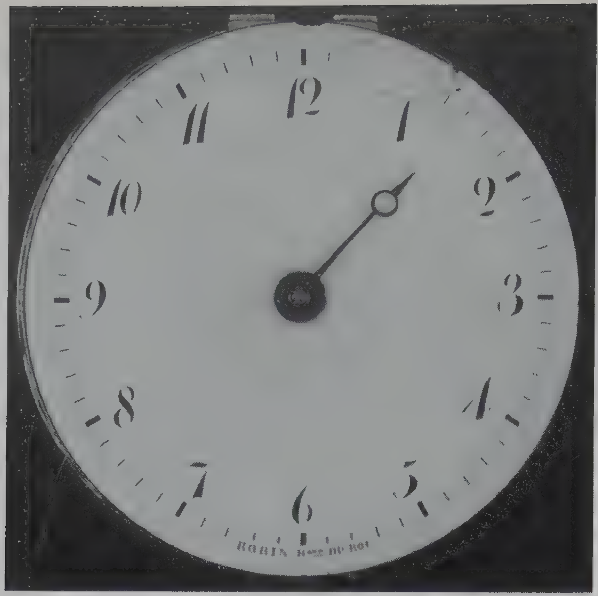
f

Plate 83

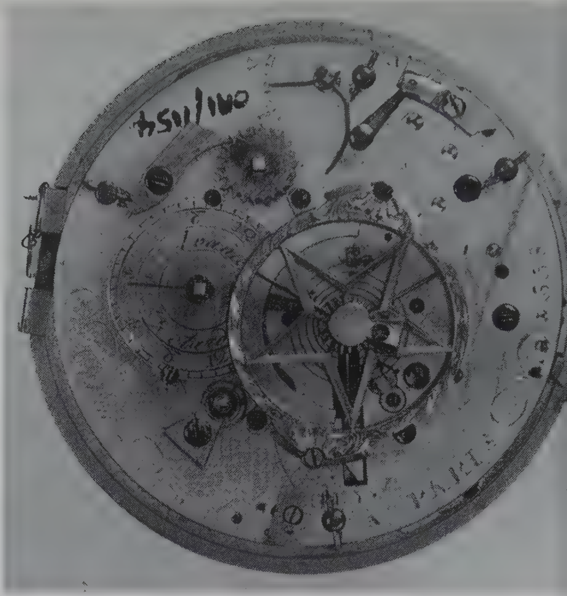
a. Cat. no. 119, balance and stud.
b. Cat. no. 120.
c. Cat. no. 120.
d. Cat. no. 120.
e. Cat. no. 120.
f. Cat. no. 120.

Plate 84

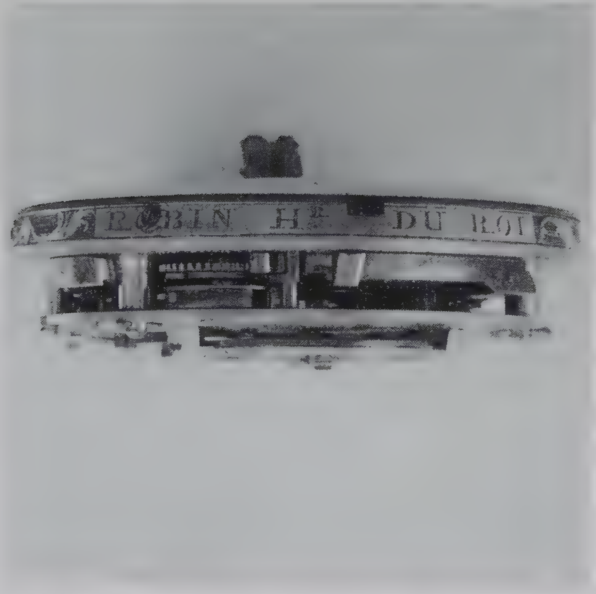
a. Cat. no. 121.
b. Cat. no. 121.
c. Cat. no. 121.
d. Cat. no. 121.
See Pl. 10e for back of dial.
e. Cat. no. 122.
f. Cat. no. 122.


ROBIN Hr DU ROI

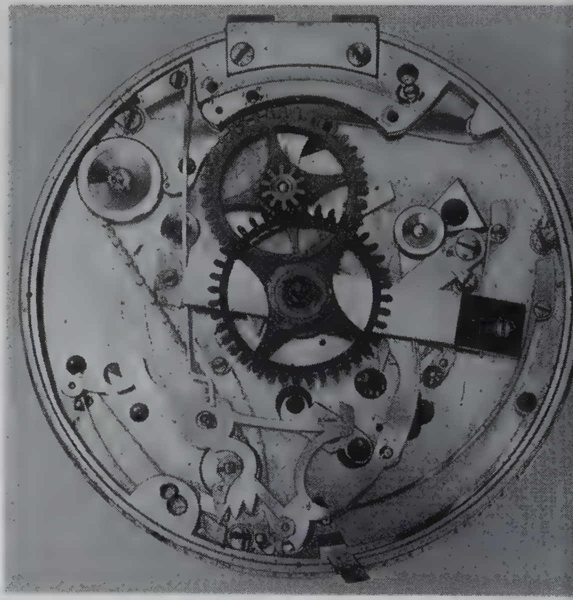
a



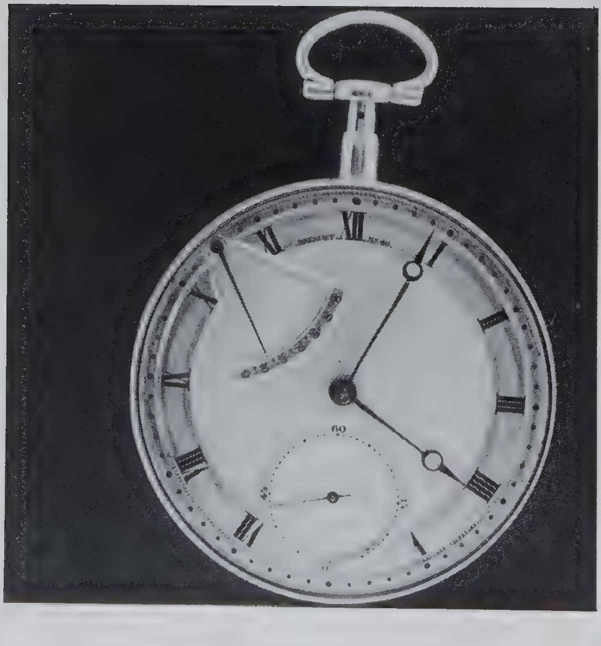
b


ROBIN Hr DU ROI

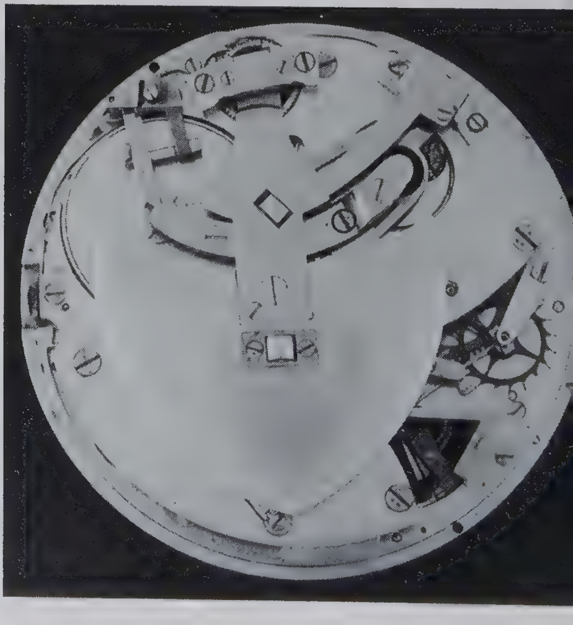
c



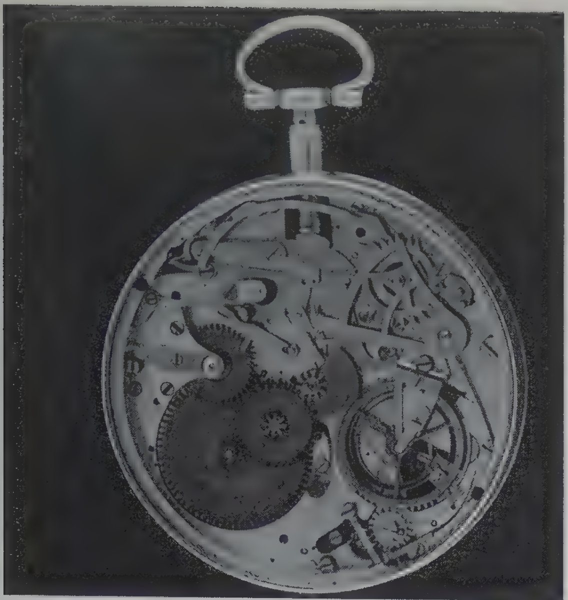
d



e



f



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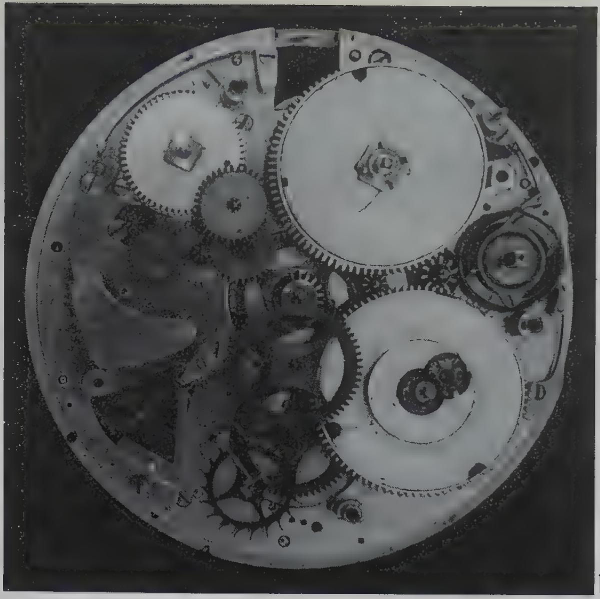
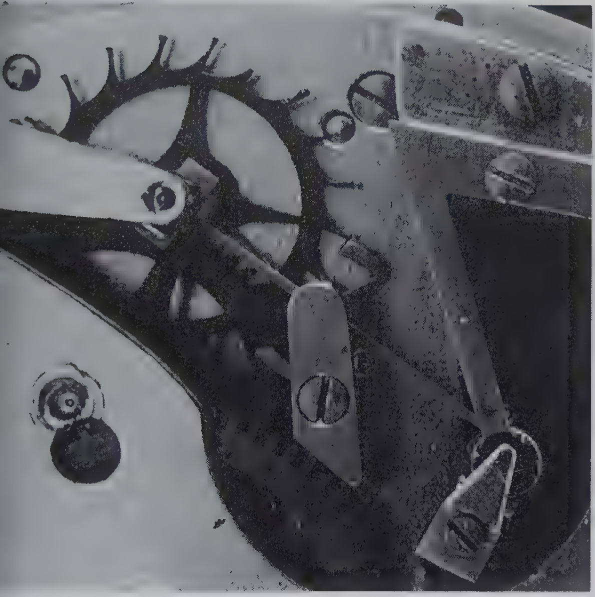
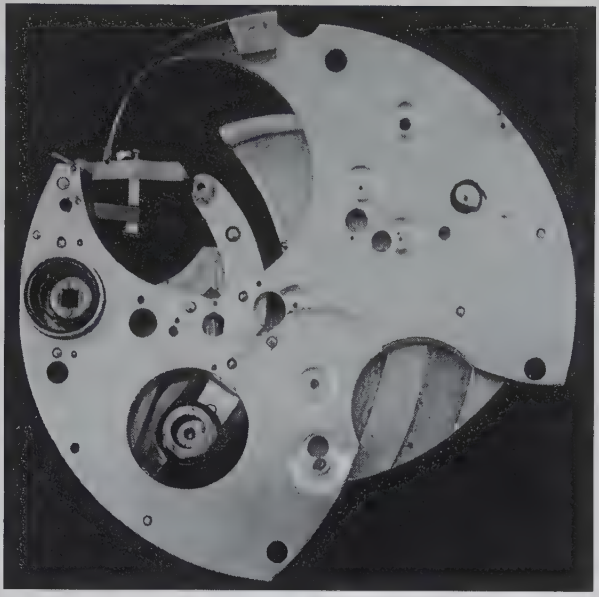


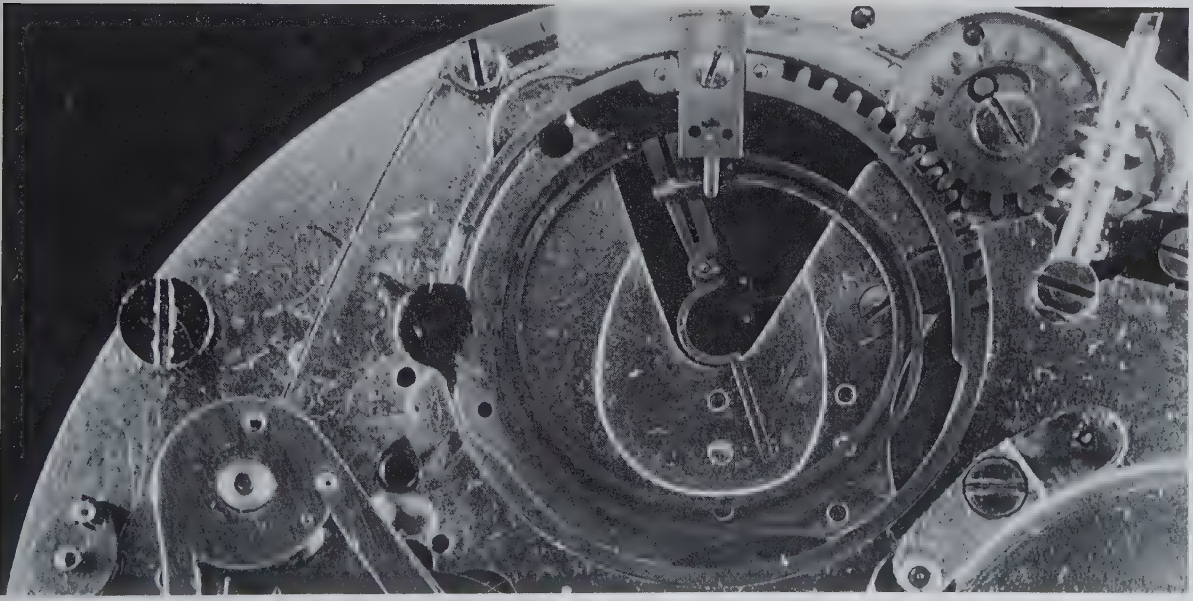
b



c



d



e

Plate 85

a. Cat. no. 122.
b. Cat. no. 122.
c. Cat. no. 122.
d. Cat. no. 122, the underside of the backplate.
e. Cat. no. 122, detail of regulator and curb.

Plate 86

a. Cat. no. 122.
b. Cat. no. 122, the self-winding train.
c. Cat. no. 123.
d. Cat. no. 123.
e. Cat. no. 123, the self-winding weight removed.
f. Cat. no. 123, the under dial view.

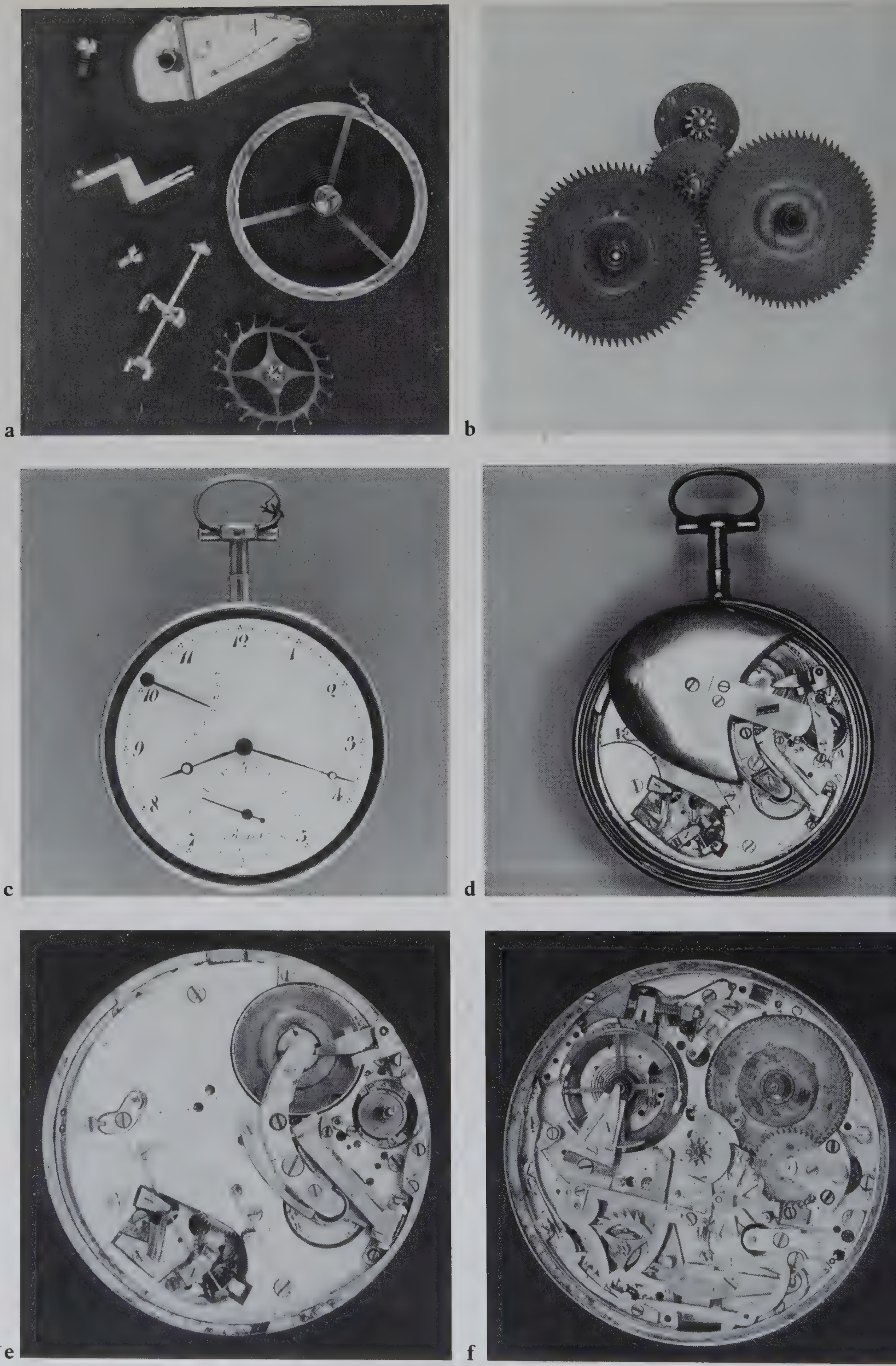


Plate 87

a. Cat. no. 123.
b. Cat. no. 123, the self-winding train.
c. Cat. no. 123.
d. Cat. no. 124.
e. Cat. no. 124.

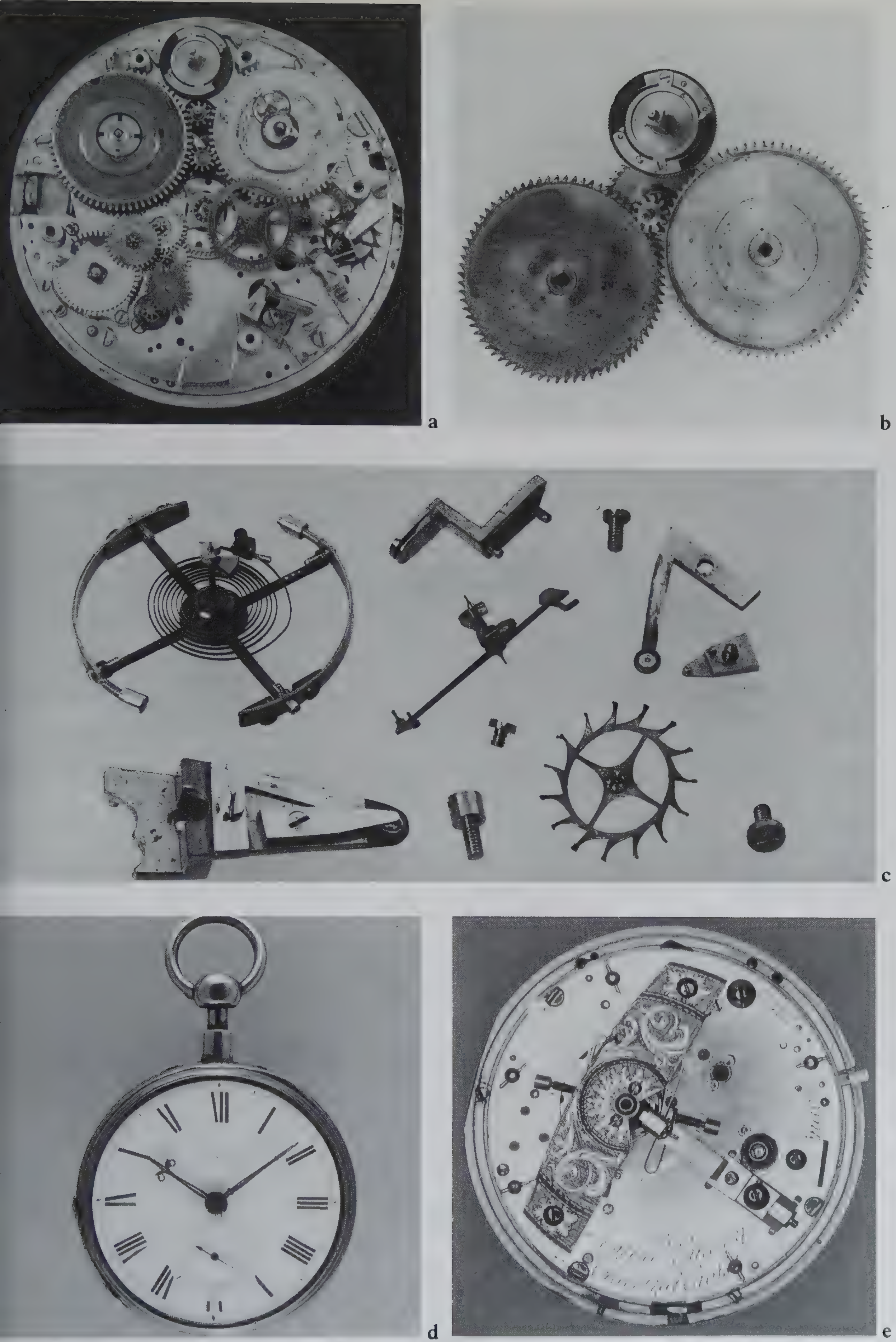
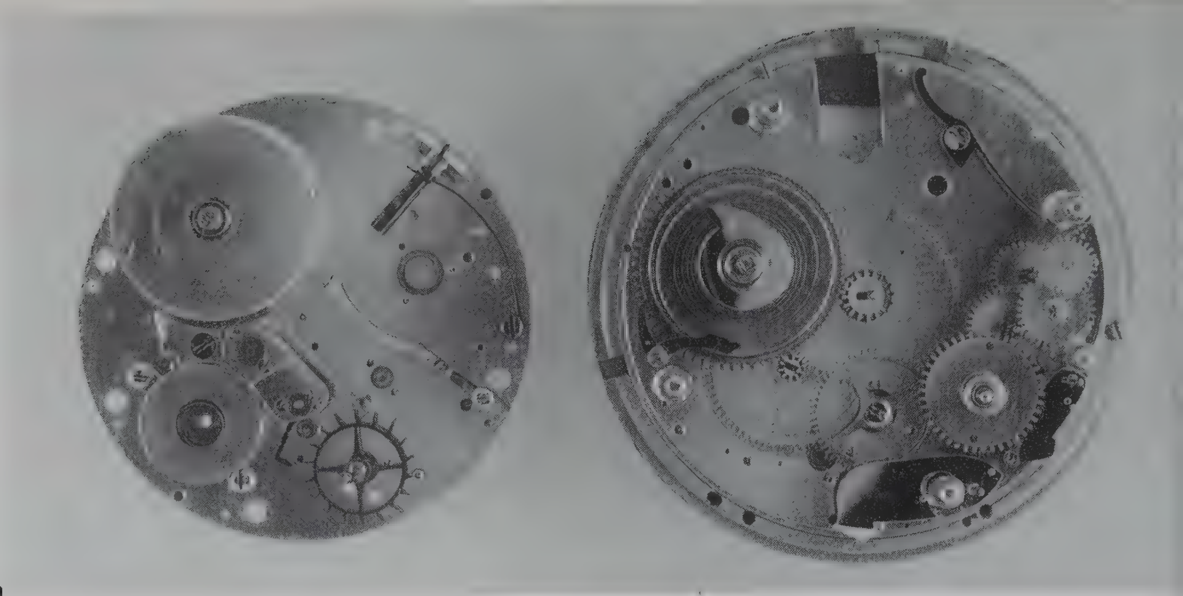


Plate 88

a. Cat. no. 124.
b. Cat. no. 124.
c. Cat. no. 124.
d. Cat. no. 124, much of the repeating work removed. Note the jewelled centre hole.
e. Cat. no. 125.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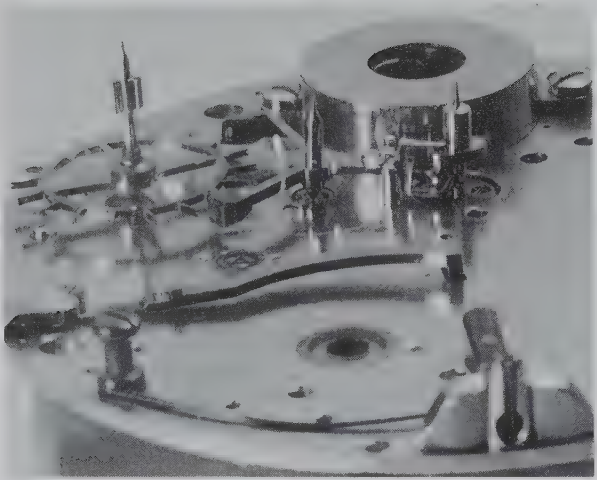
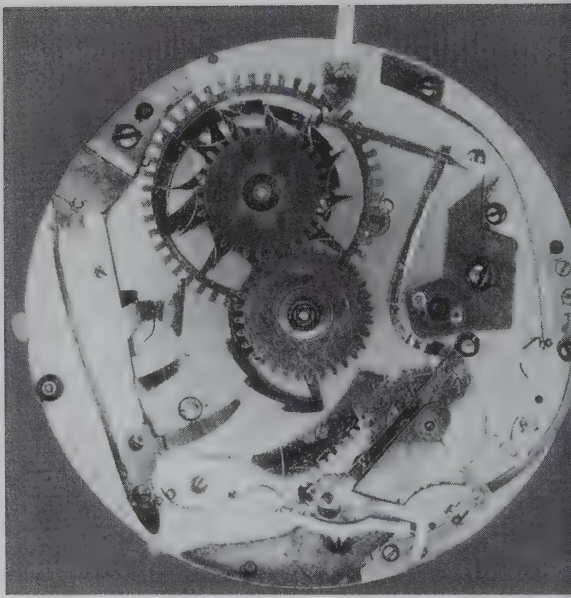
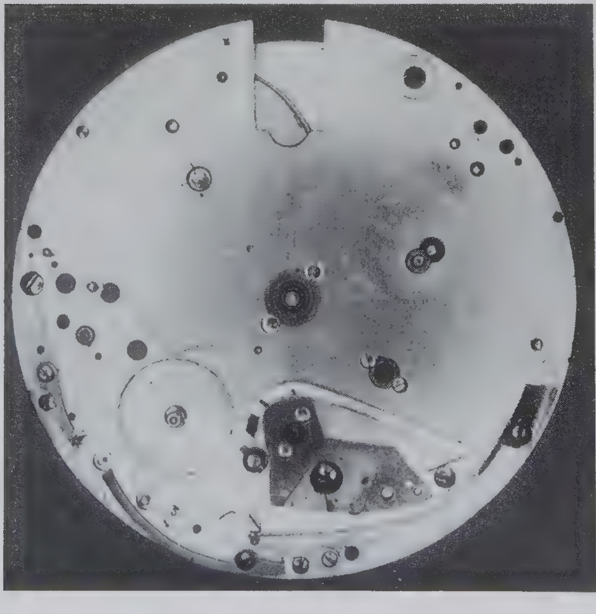

b


c


d

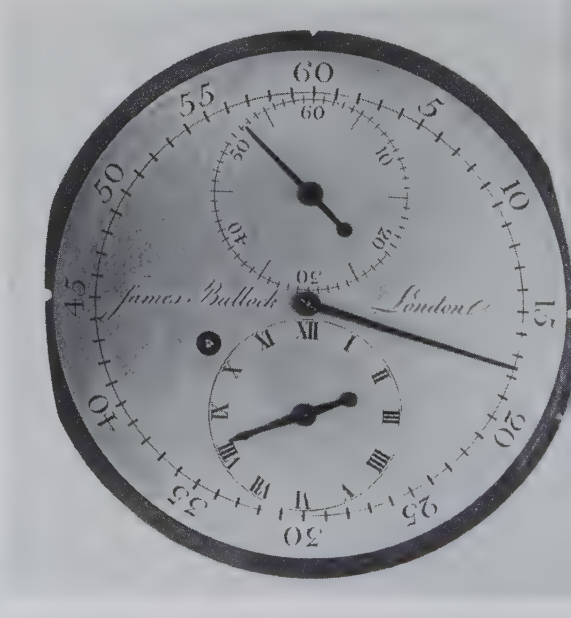
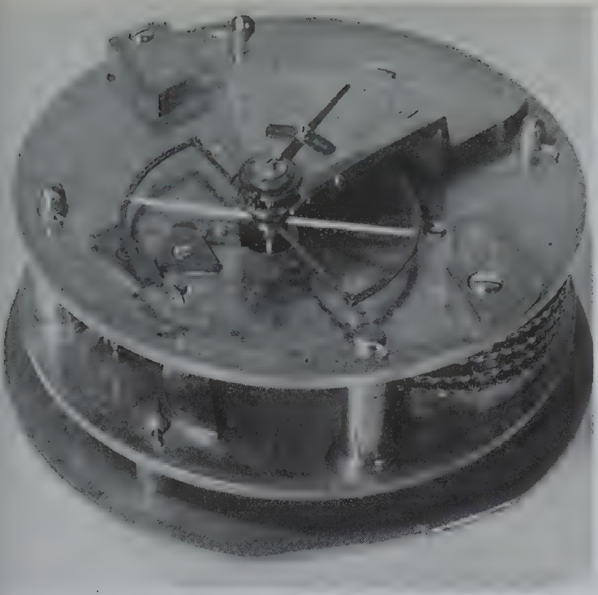
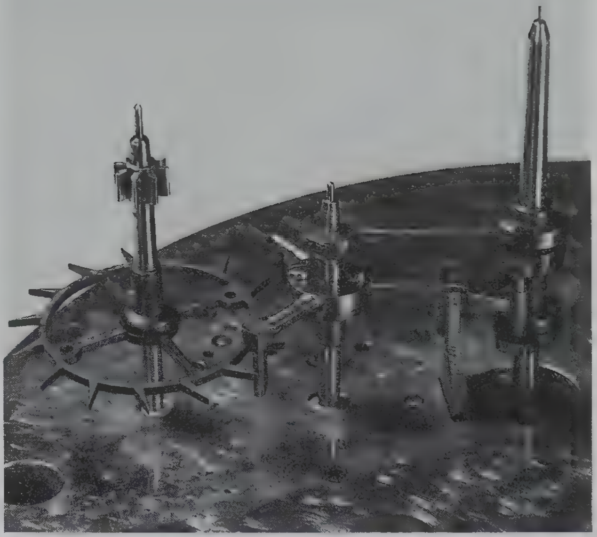

James Bullock London
e

Plate 89

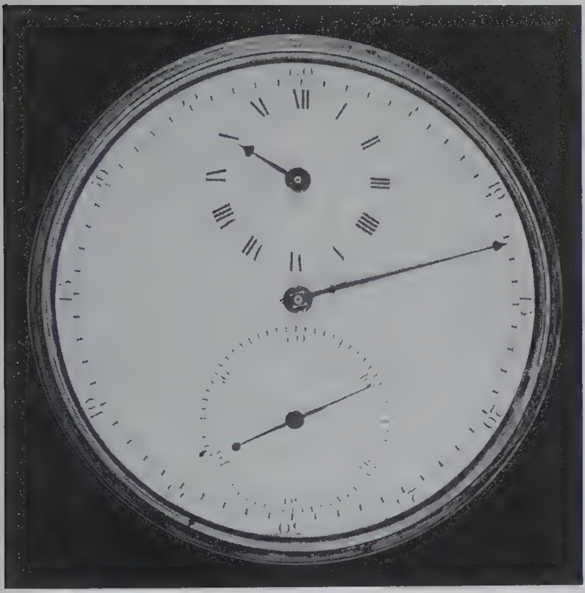
- **a.** Cat. no. 125.
- **b.** Cat. no. 125.
- **c.** Cat. no. 126.
- **d.** Cat. no. 126.
- **e.** Cat. no. 126.



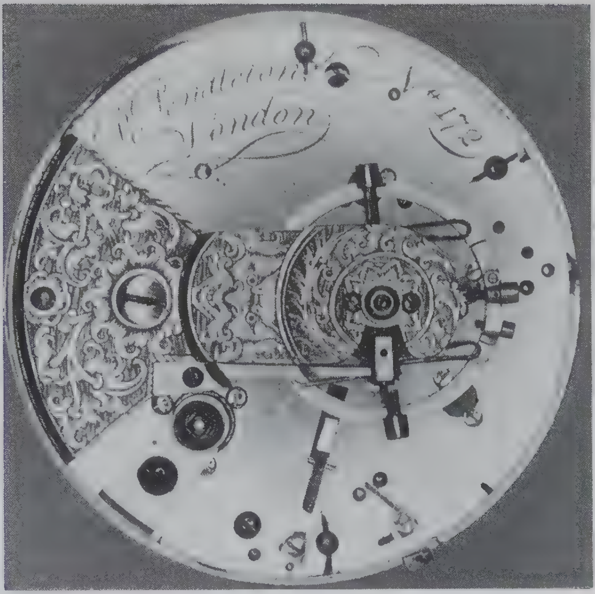
a



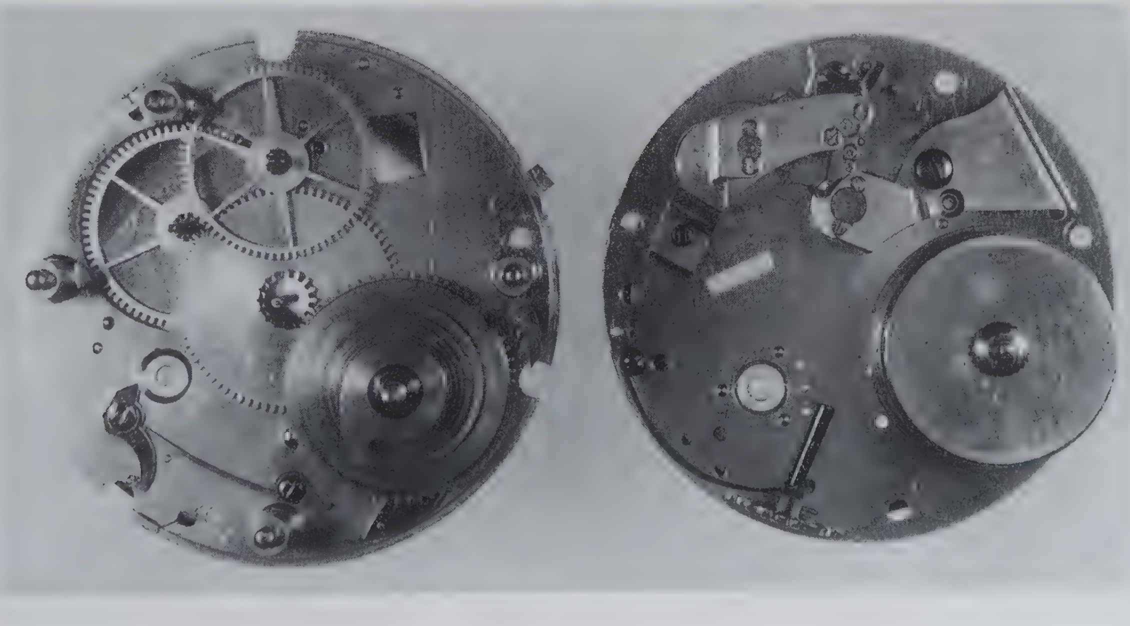
b



c



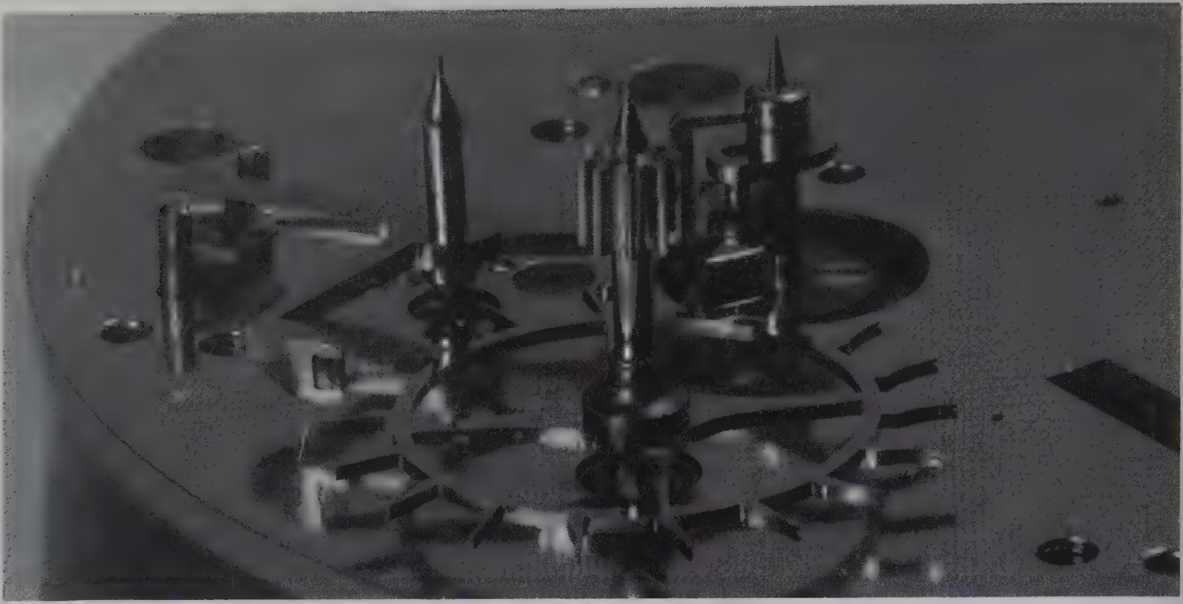
d

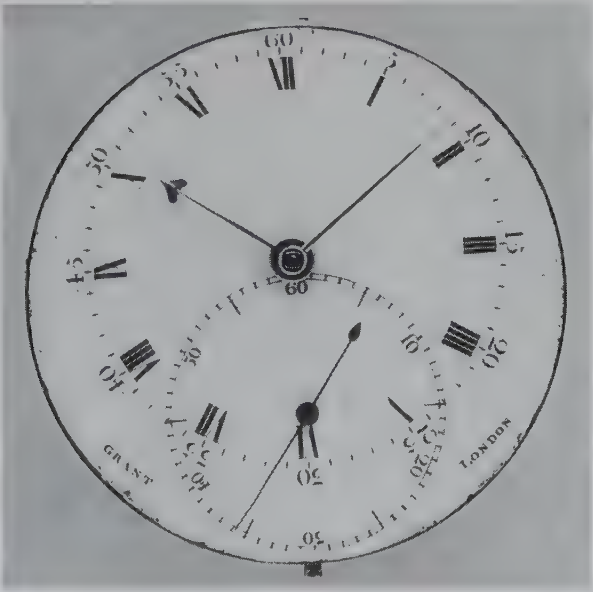


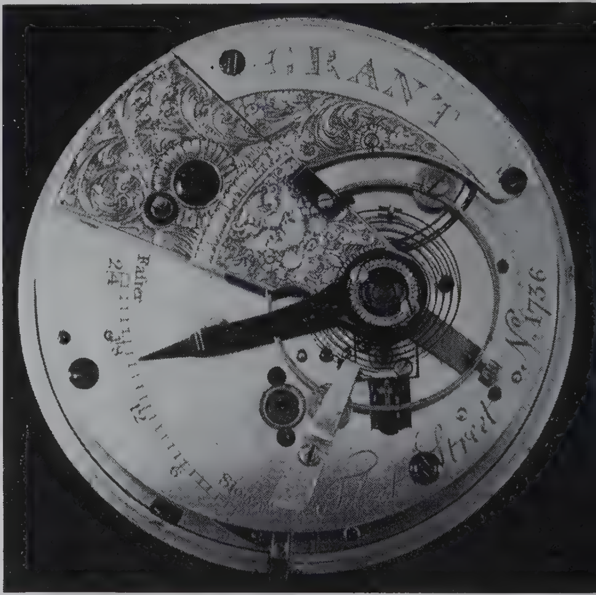
e

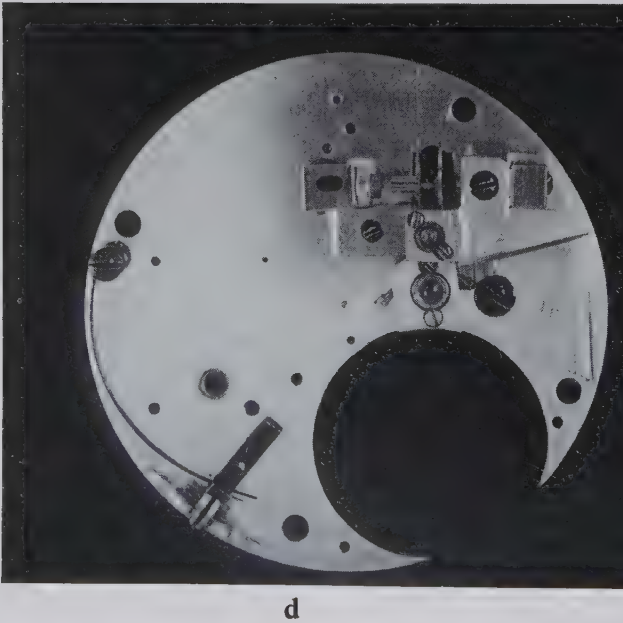
Plate 90

a. Cat. no. 126.
b. Cat. no. 127.
c. Cat. no. 127.
d. Cat. no. 127.
e. Cat. no. 127.


a


GRANT
LONDON
60
b


GRANT
No 1736
Street
Faster
Slower
c


d

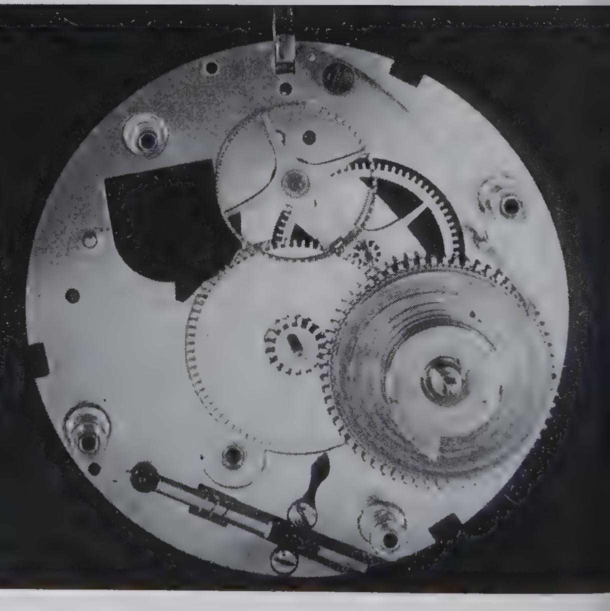
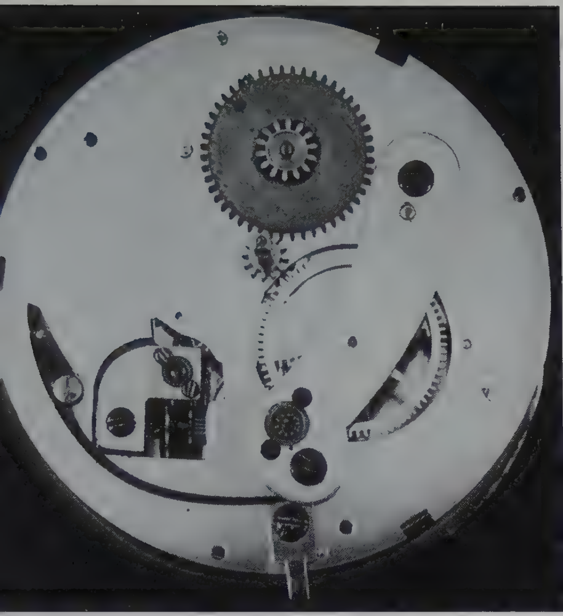
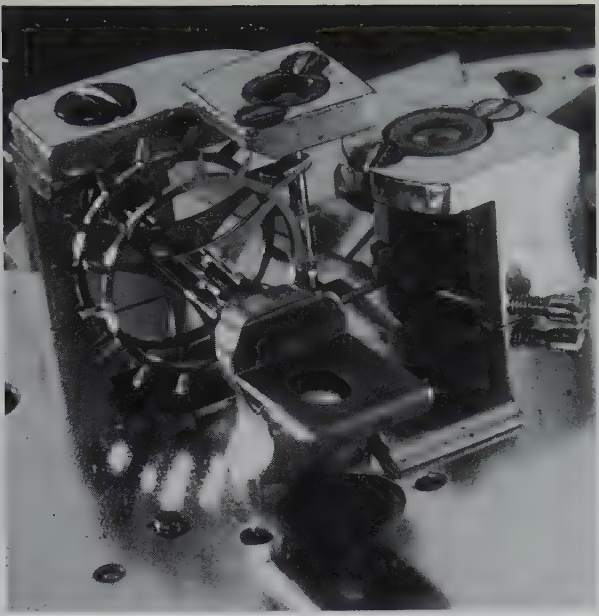
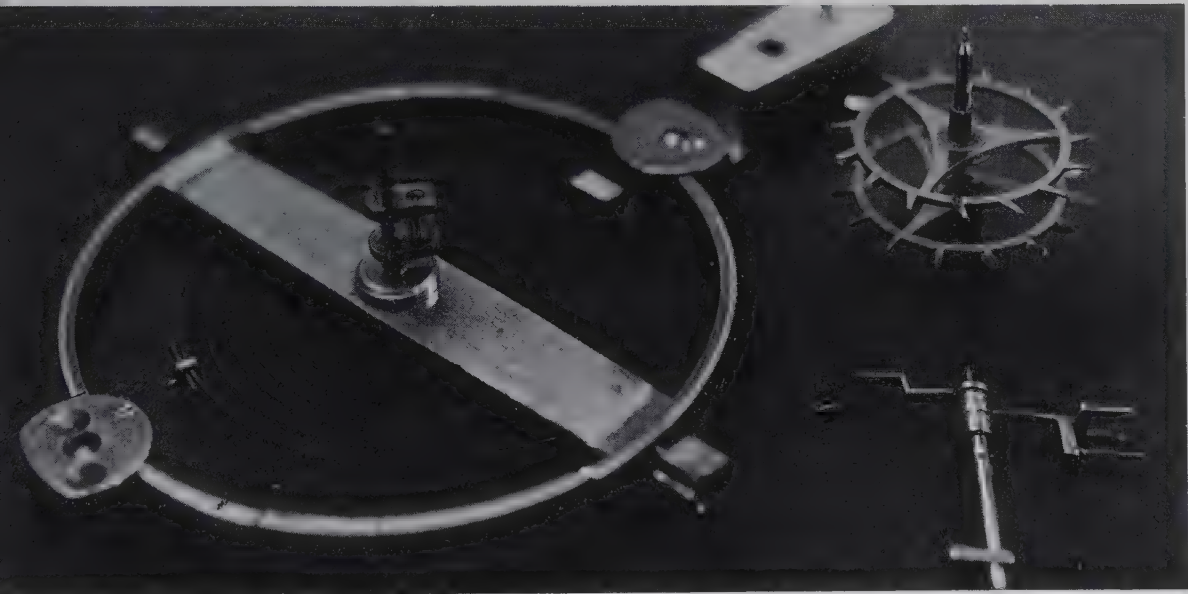

e

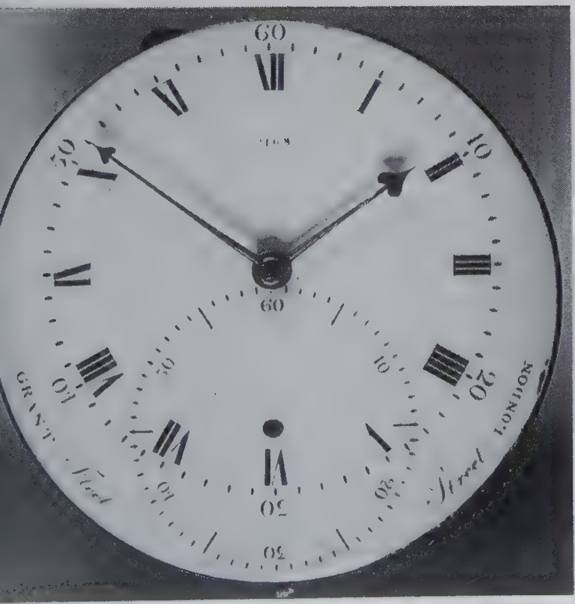
Plate 91

- **a.** Cat. no. 127.
- **b.** Cat. no. 127.
- **c.** Cat. no. 127.
- **d.** Cat. no. 128.
- **e.** Cat. no. 128.


a


b


c


GRANT Fleet Street LONDON
d

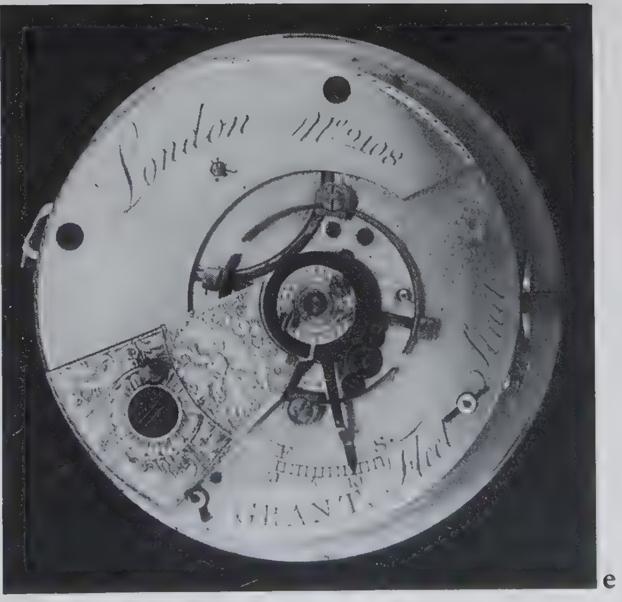
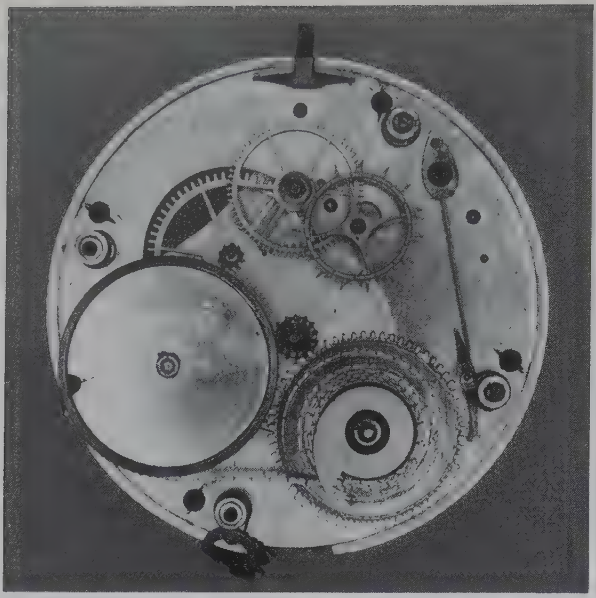
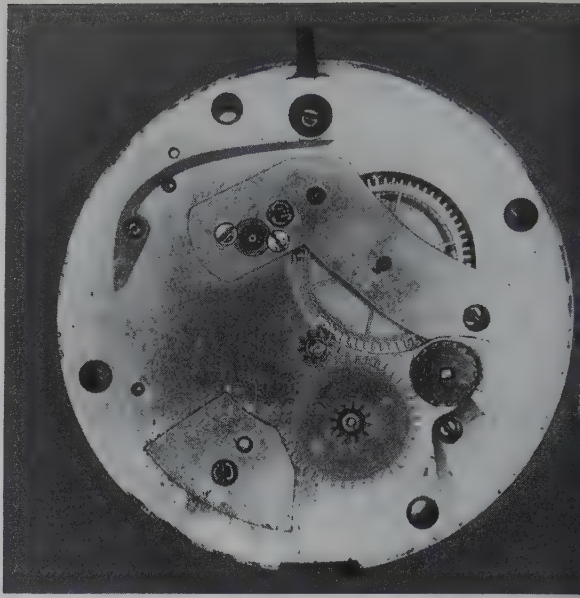
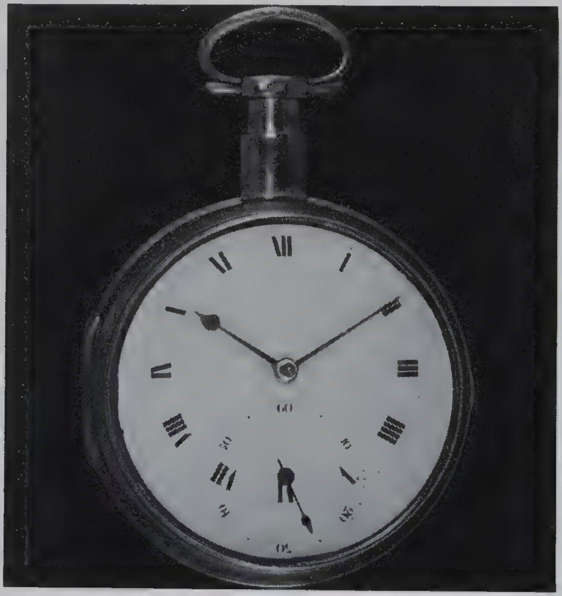

London No. 2108
GRANT Fleet Street
e

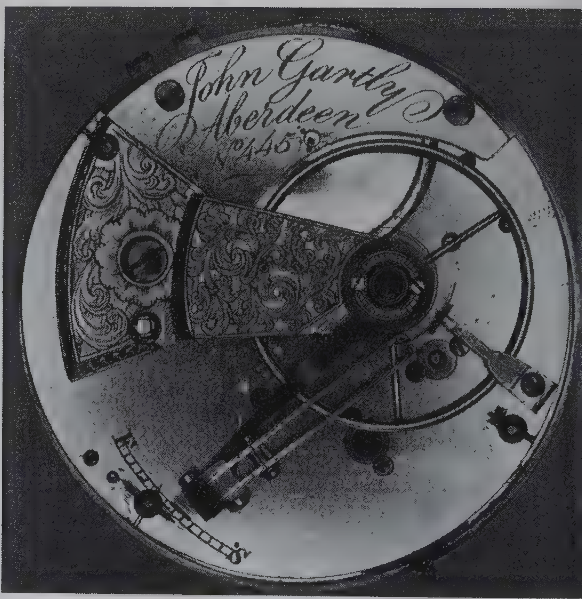
Plate 92

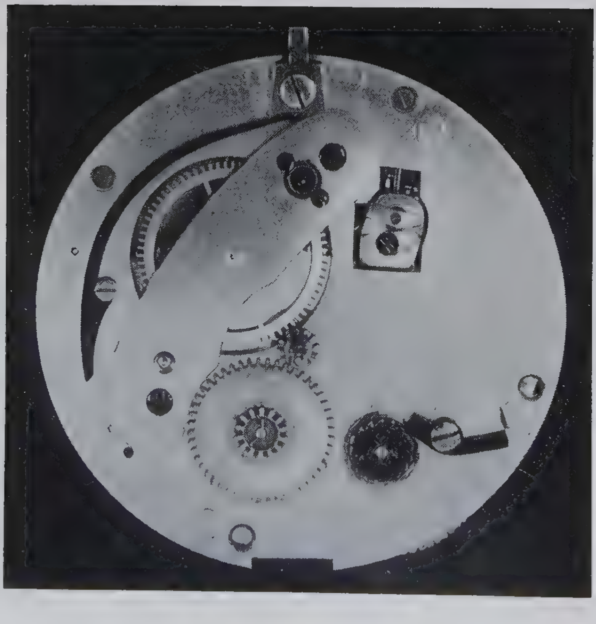
a. Cat. no. 128.
b. Cat. no. 128.
c. Cat. no. 129.
d. Cat. no. 129.
e. Cat. no. 129.
f. Cat. no. 129.

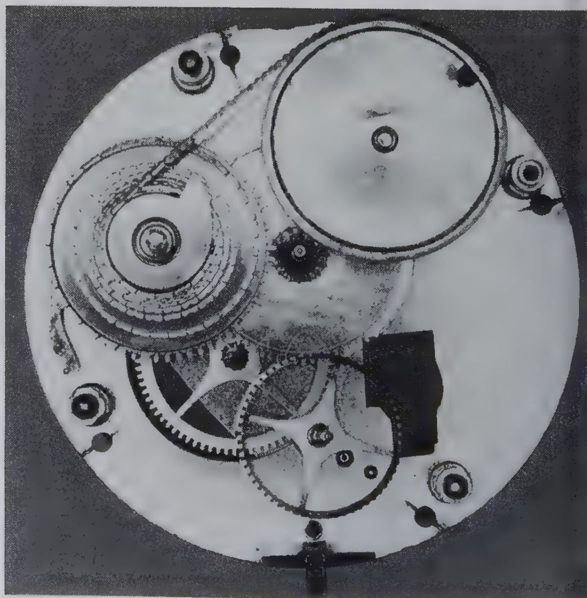

a


b


c


John Gartly
Aberdeen
No 145
F
S
d


e


f

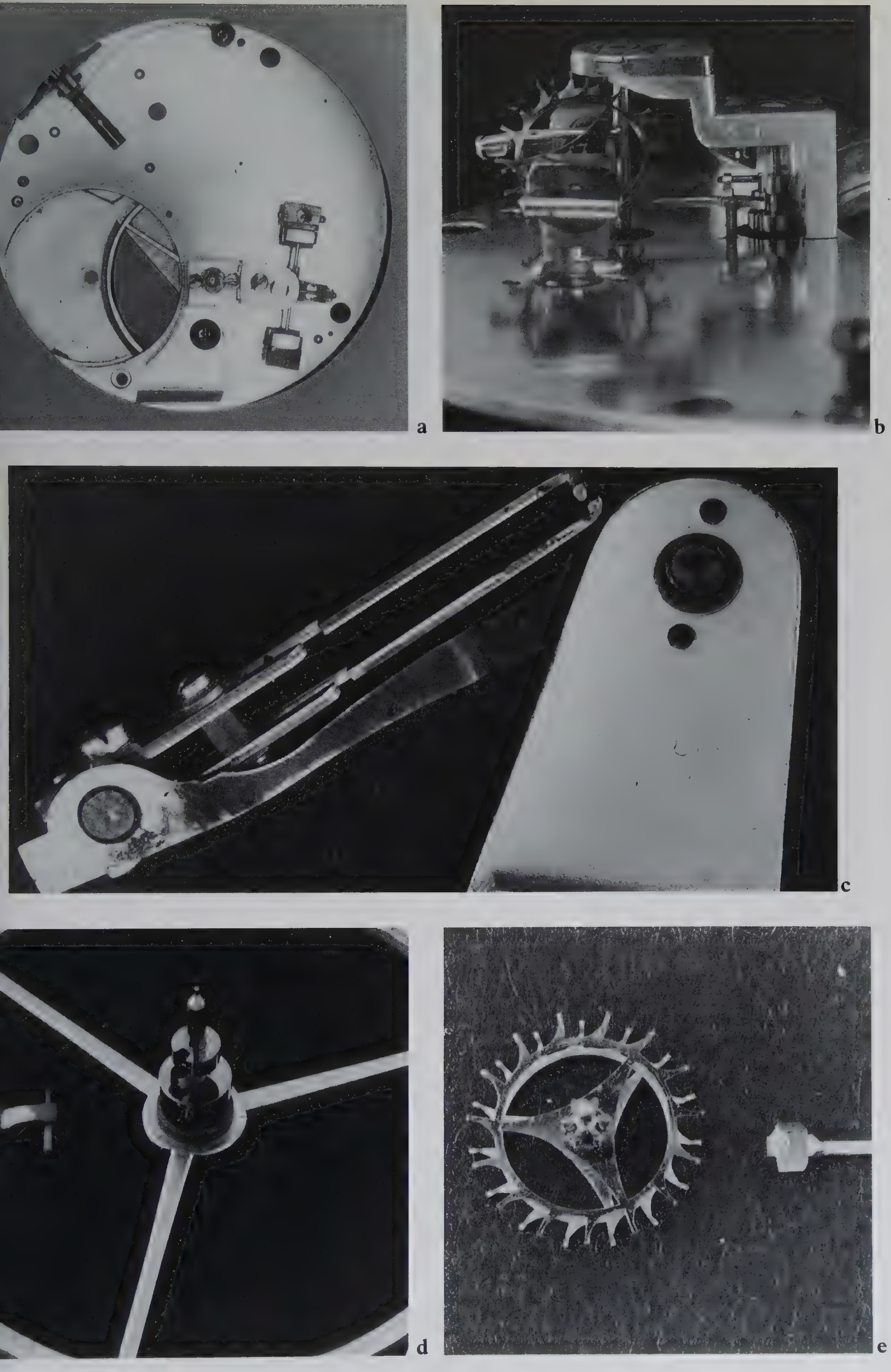
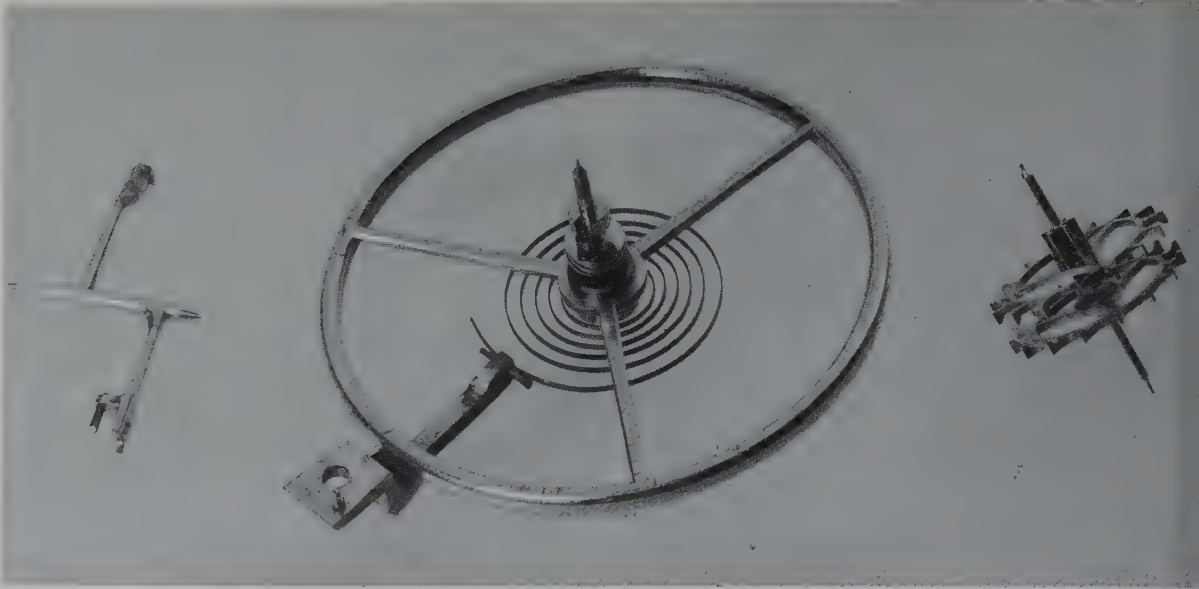


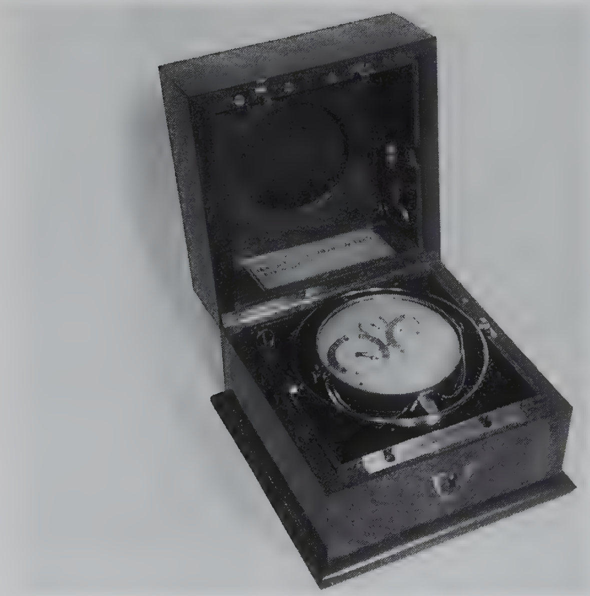
Plate 93

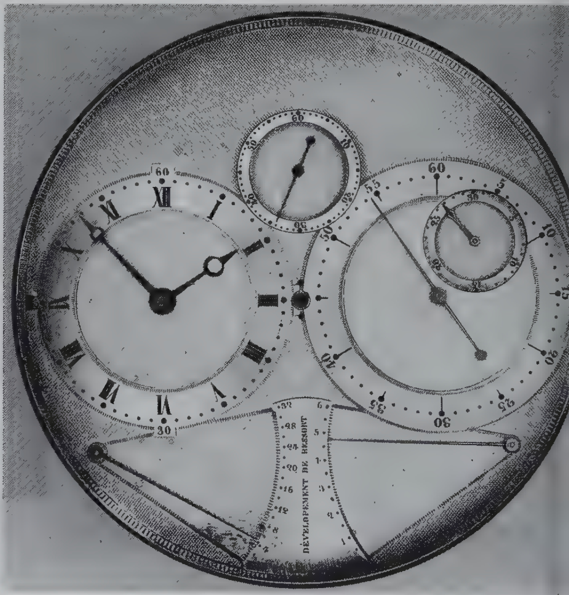
a. Cat. no. 129, the inside of the backplate with potances for balance and escape wheel.
b. Cat. no. 129, escapement.
c. Cat. no. 129, temperature compensation.
d. Cat. no. 129, impulse and safety roller.
e. Cat. no. 129, escape wheel and pallets.

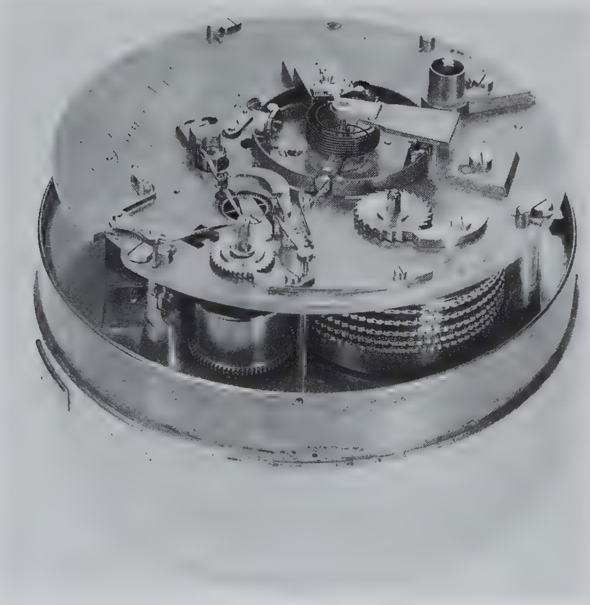
Plate 94

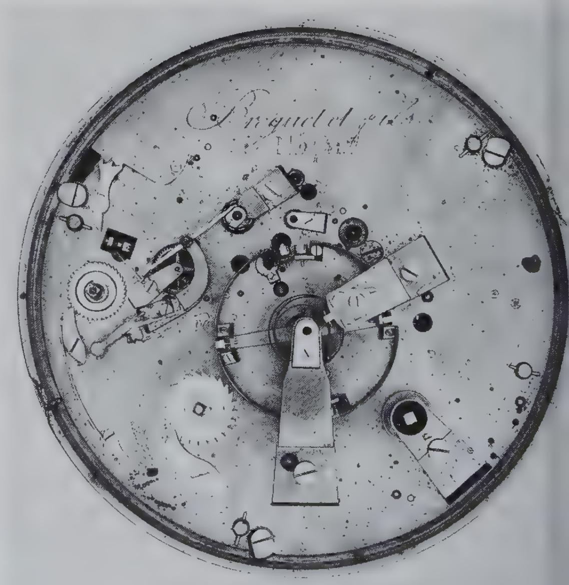
- **a.** Cat. no. 129.
- **b.** Cat. no. 130.
- **c.** Cat. no. 130.
- **d.** Cat. no. 130.
- **e.** Cat. no. 130.


a


b


DEVELOPEMENT DE RESSORT
c


d


Breguet et fils
e

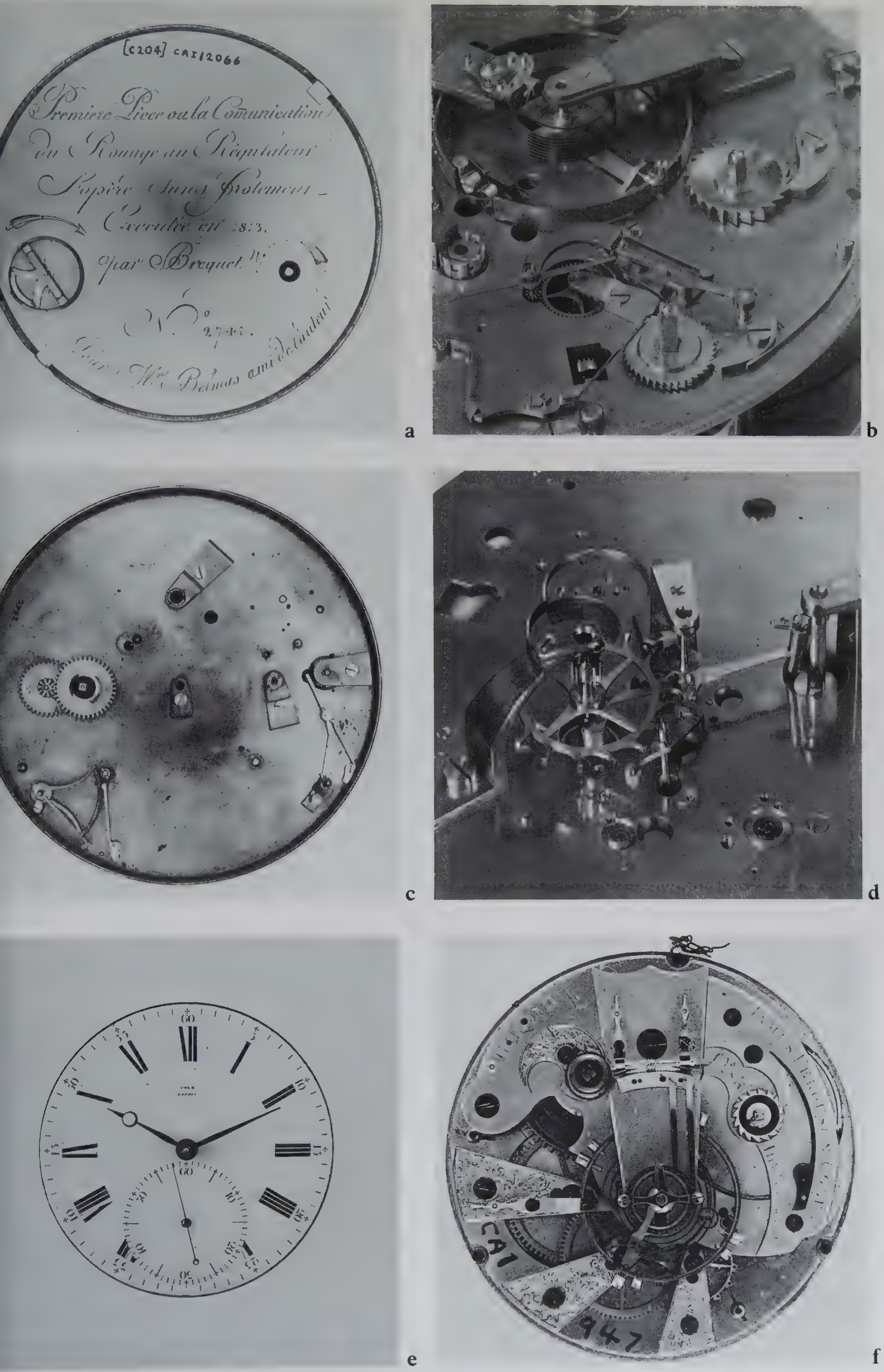
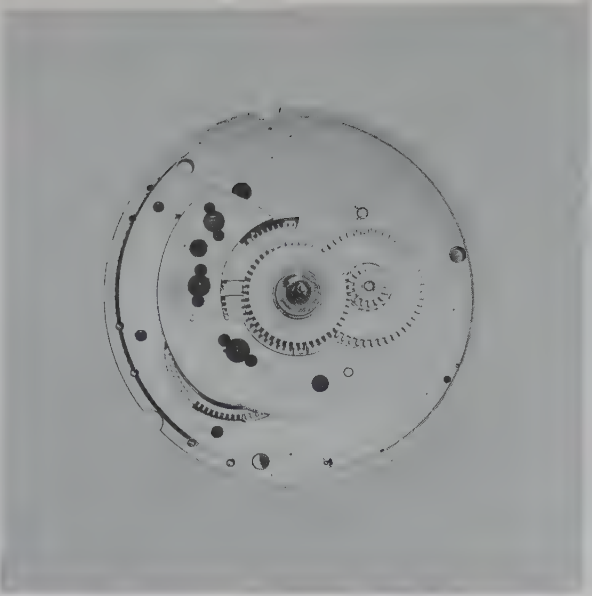

[C204] CAI/2066
Premiere Piece ou la Comunication
du Rouage au Régulateur
S'opère Sans frotement -
Executée en 1823.
par Breguet
N° 2742.
Pour Mr. Belmas ami de l'auteur
a
b
c
d
60
5
10
15
20
25
30
35
40
45
50
55
60
10
20
30
40
50
e
CA1
947
f

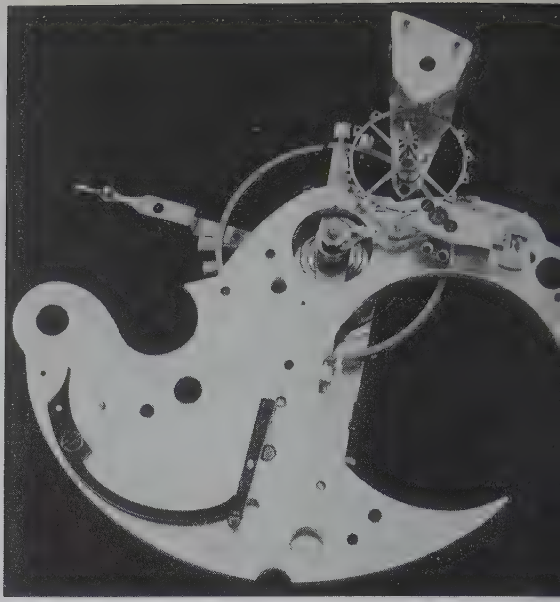
Plate 95

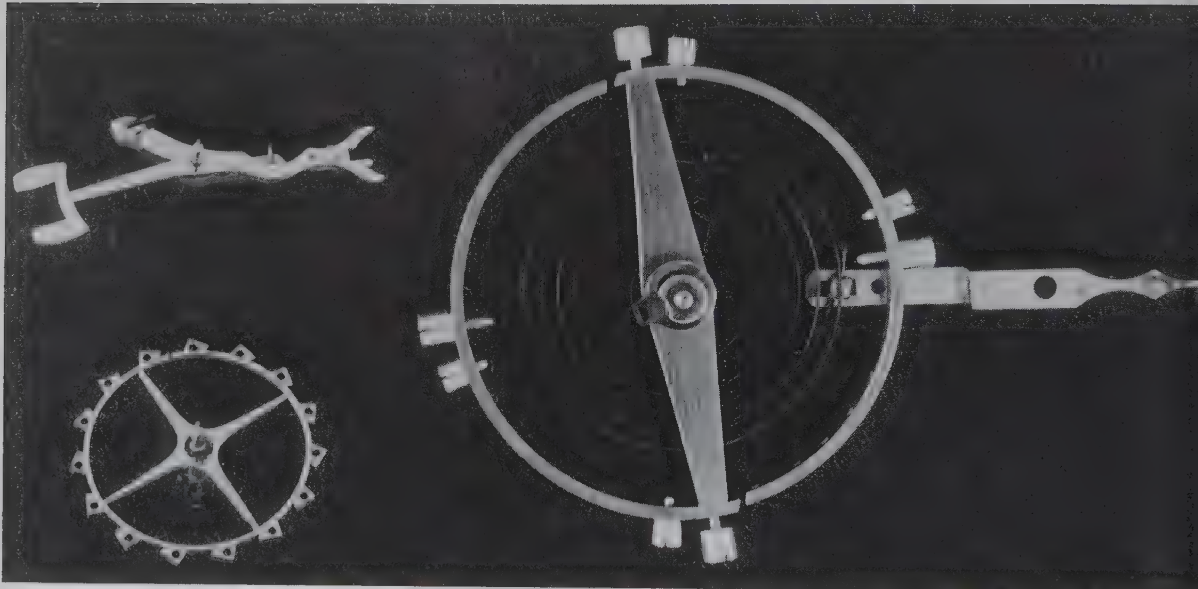
a. Cat. no. 130.
b. Cat. no. 130.
c. Cat. no. 130, under dial.
d. Cat. no. 130.
e. Cat. no. 131.
f. Cat. no. 131.

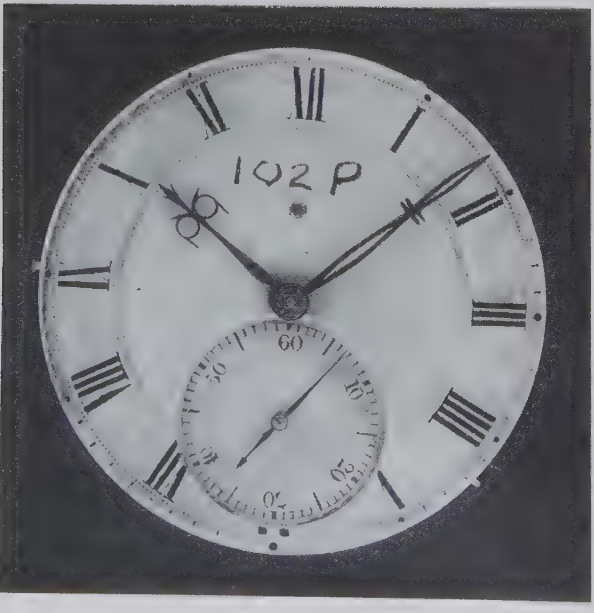
Plate 96

a. Cat. no. 131.
b. Cat. no. 131.
c. Cat. no. 131.
d. Cat. no. 132.
e. Cat. no. 132.


a


b


c



d

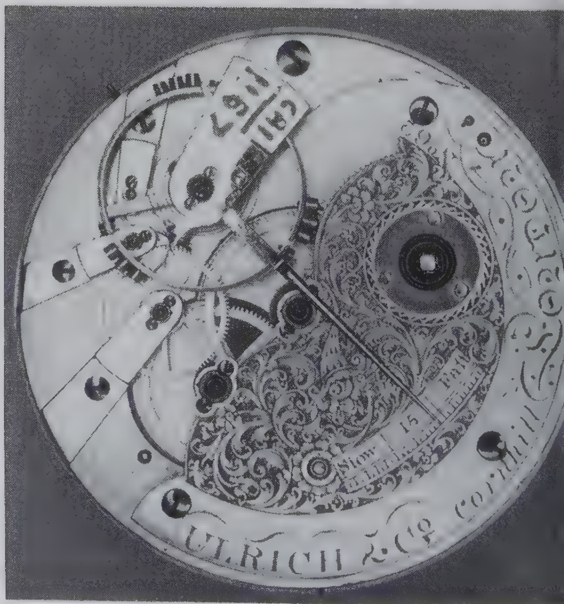
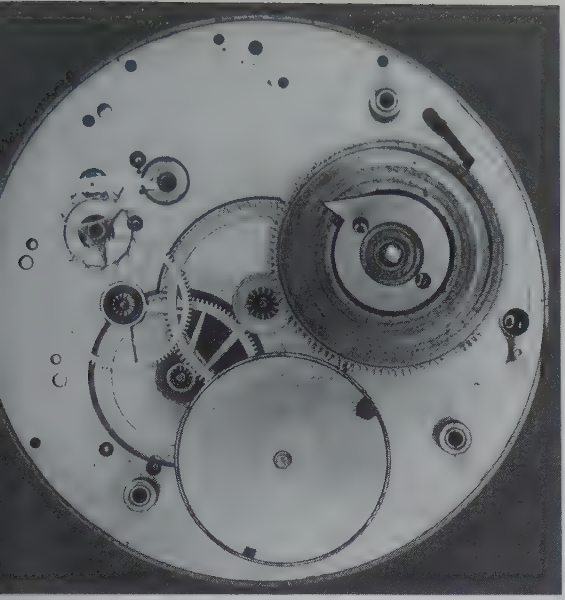
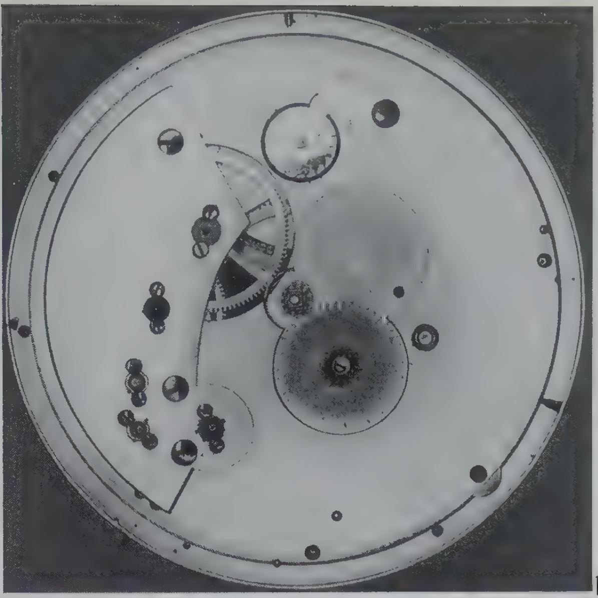
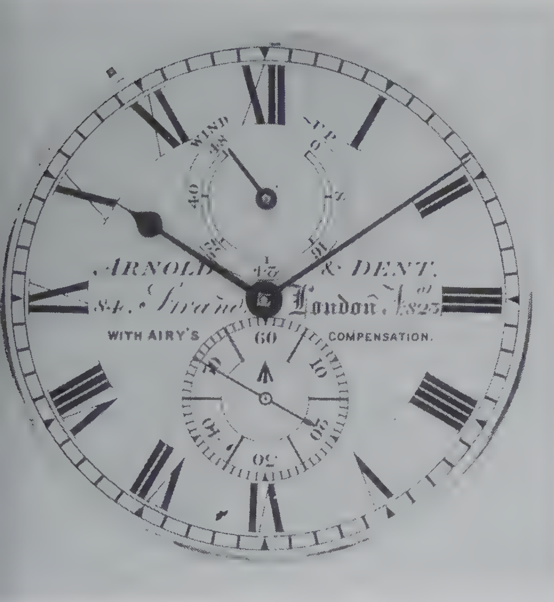

ULRICH & Co Cornhill
Slow
15
e

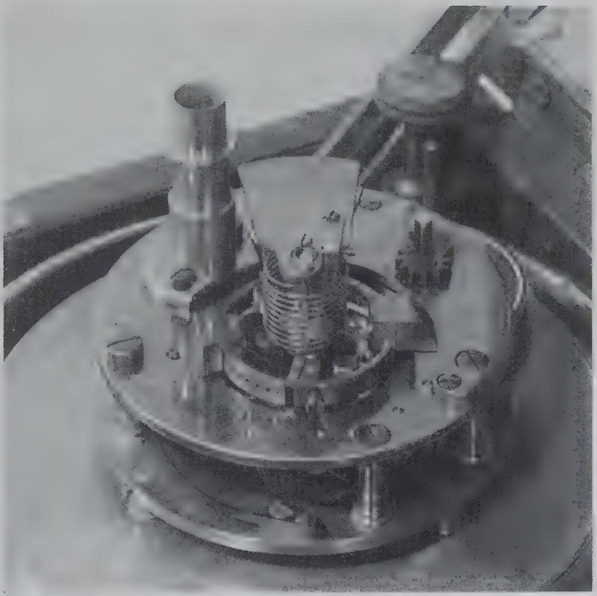
Plate 97

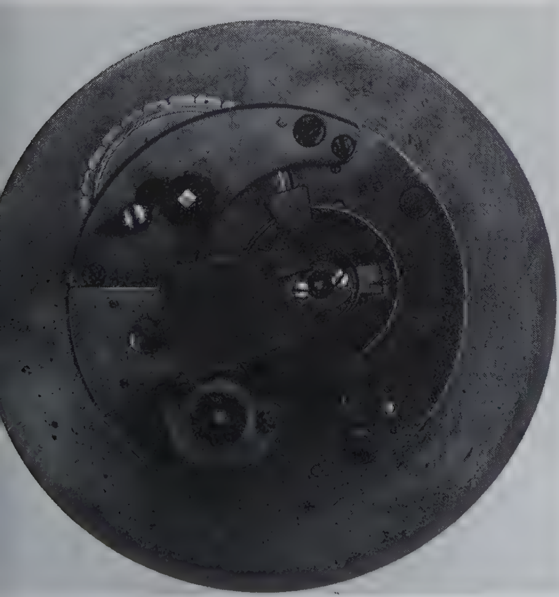
a. Cat. no. 132.
b. Cat. no. 132.
c. Cat. no. 133.
d. Cat. no. 133.
e. Cat. no. 133.
f. Cat. no. 133.


a


b


WIND UP
ARNOLD & DENT.
84. Strand London No 1823
WITH AIRY'S COMPENSATION.
c


d


e

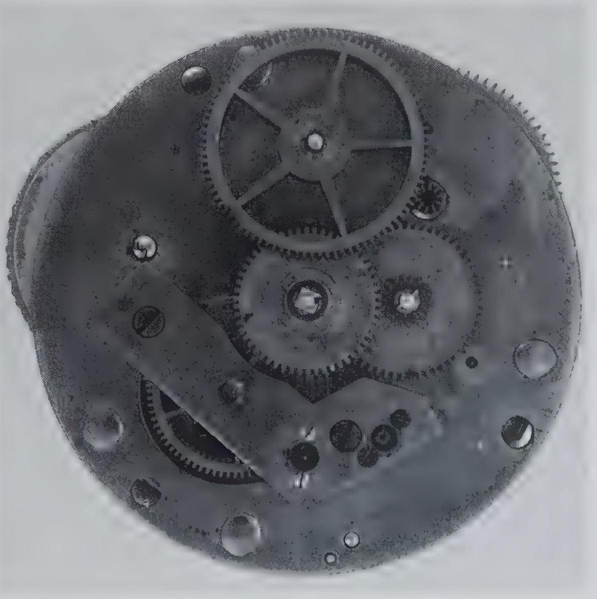
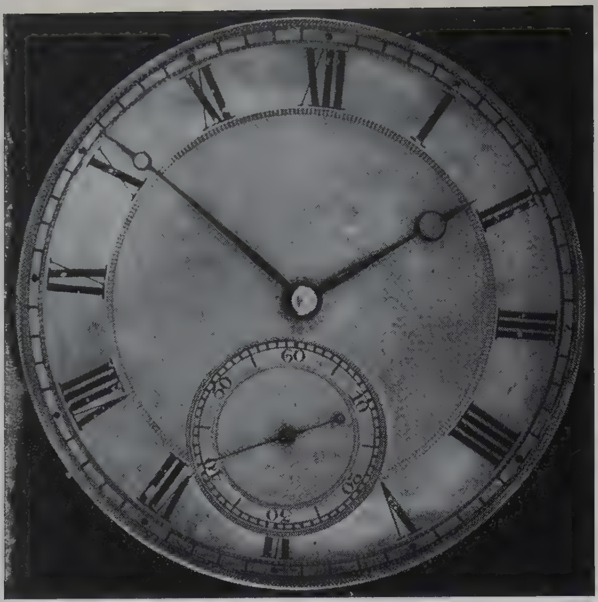
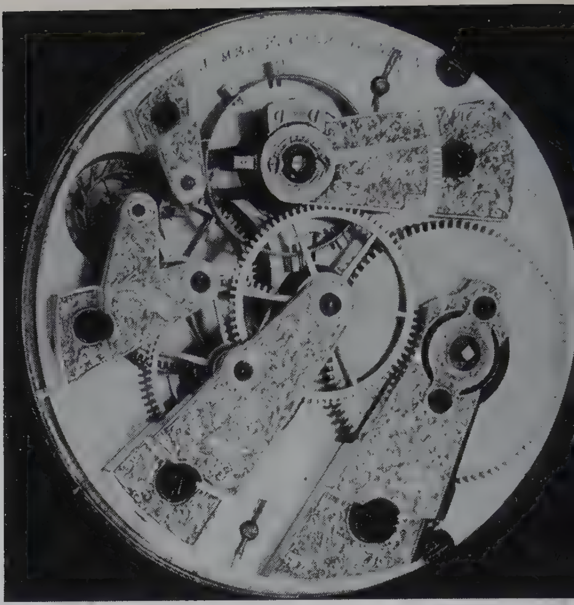
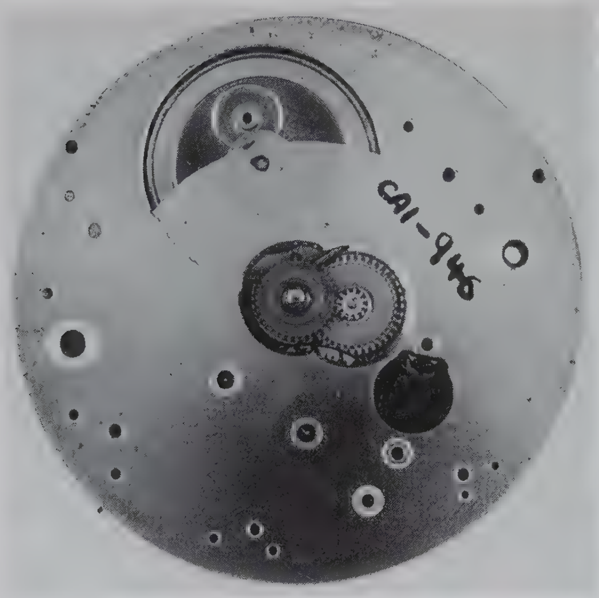

f

Plate 98

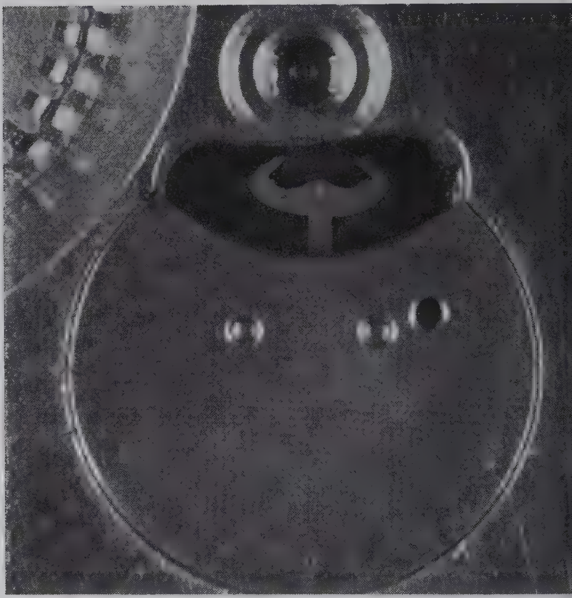
a. Cat. no. 134.
b. Cat. no. 134.
c. Cat. no. 134.
d. Cat. no. 134, detail of the very wide lever notch.
e. Cat. no. 135.
f. Cat. no. 135.

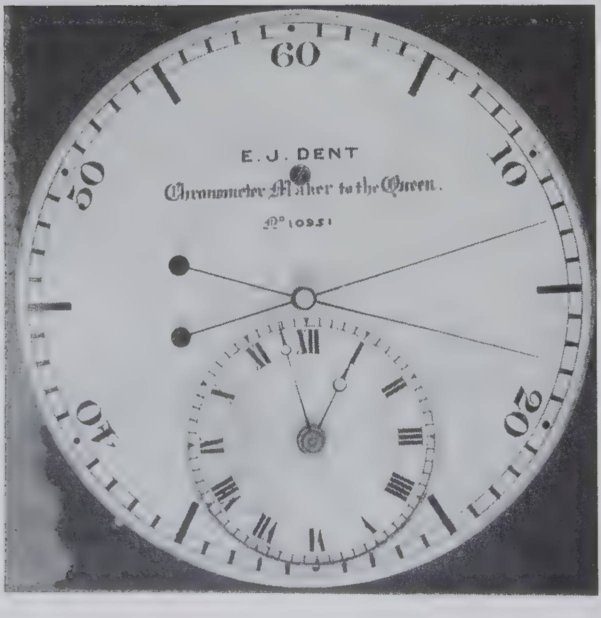

a

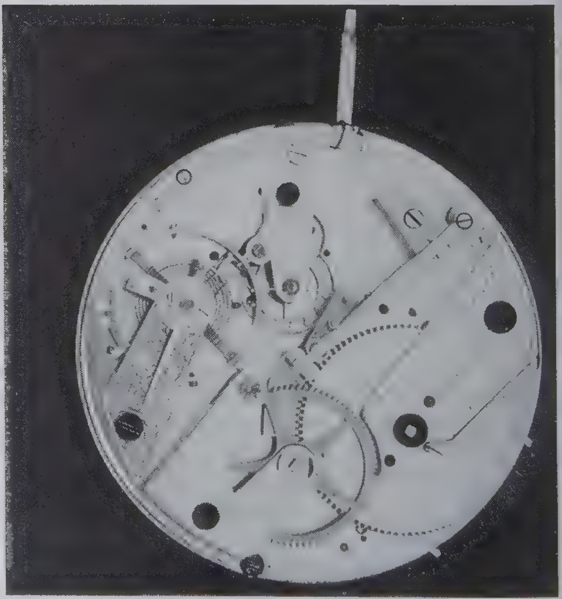

b



c


d


60
10
20
40
50
E.J. DENT
Chronometer Maker to the Queen.
No 10951
e


f

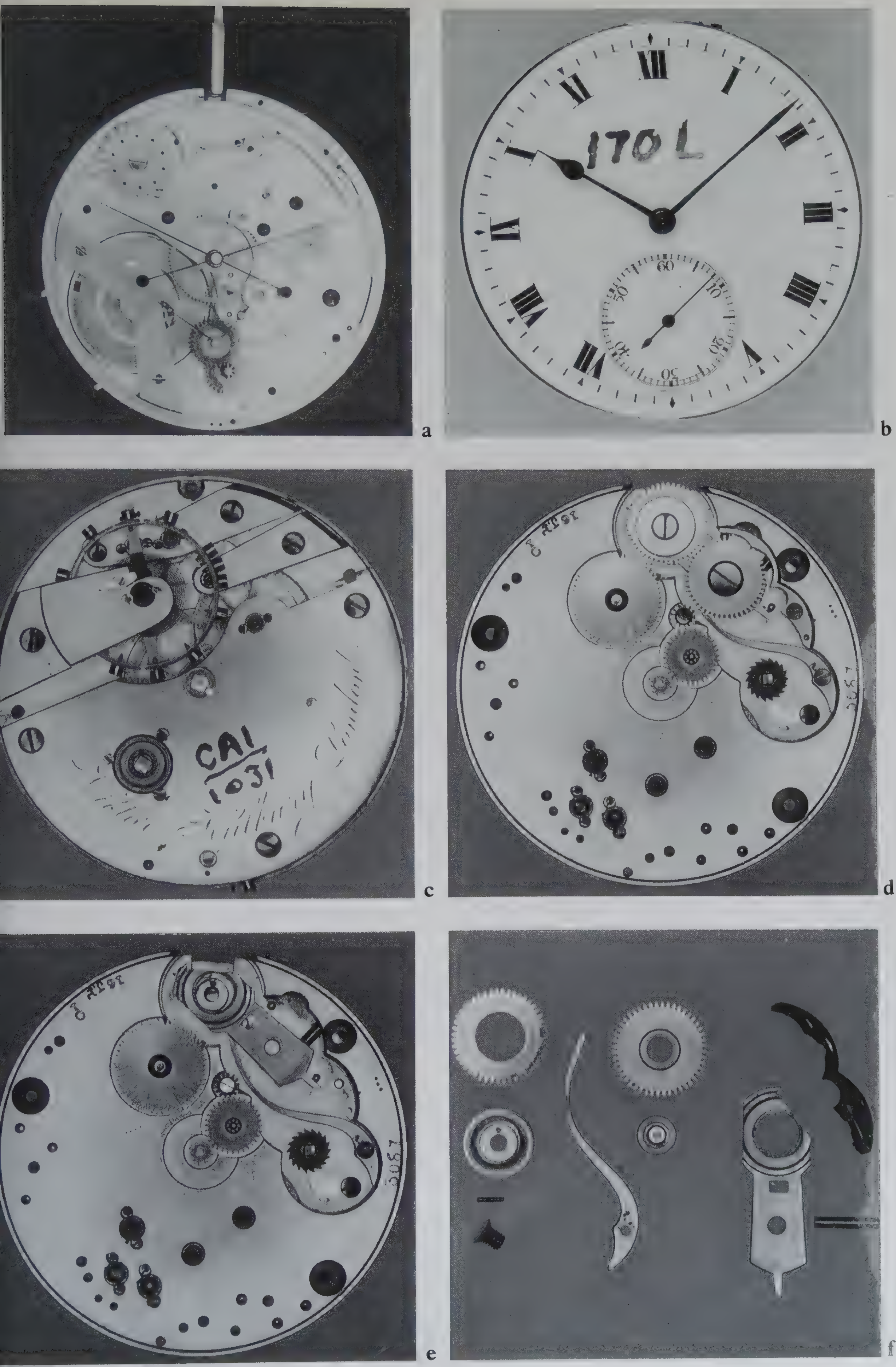
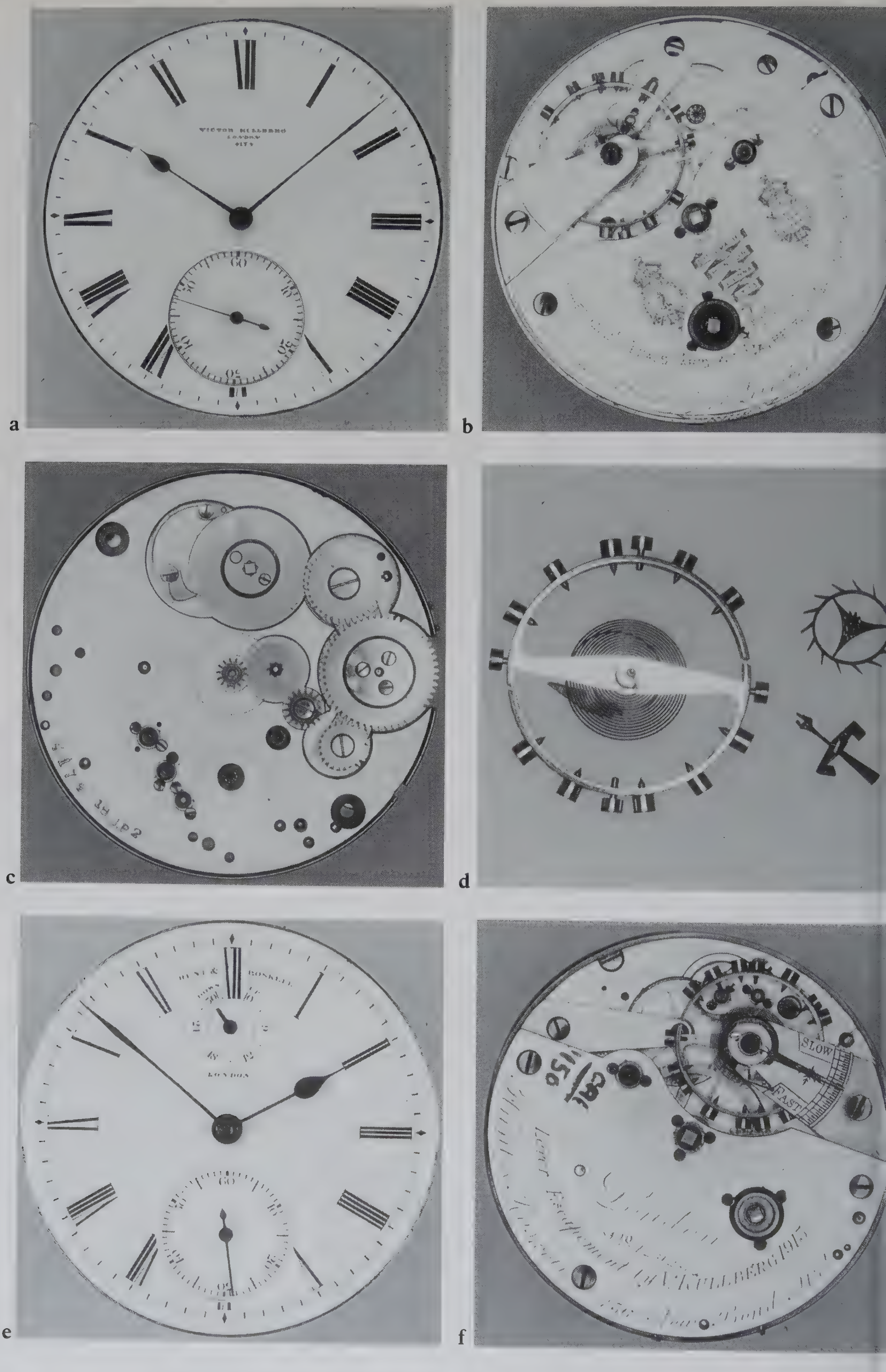

a
170 L
60
10
20
30
40
50
b
CA1
1031
c
d
e
f

Plate 99

a. Cat. no. 135.
b. Cat. no. 136.
c. Cat. no. 136.
d. Cat. no. 136.
e. Cat. no. 136.
f. Cat. no. 136, the keyless work dismantled.

Plate 100

a. Cat. no. 137.
b. Cat. no. 137.
c. Cat. no. 137.
d. Cat. no. 137.
e. Cat. no. 138.
f. Cat. no. 138.


a
VICTOR KULLBERG
LONDON
4174
b
c
d
e
HUNT & ROSKELL
LONDON
f
SLOW
FAST
150
Lever Escapement
V. KULLBERG 1915

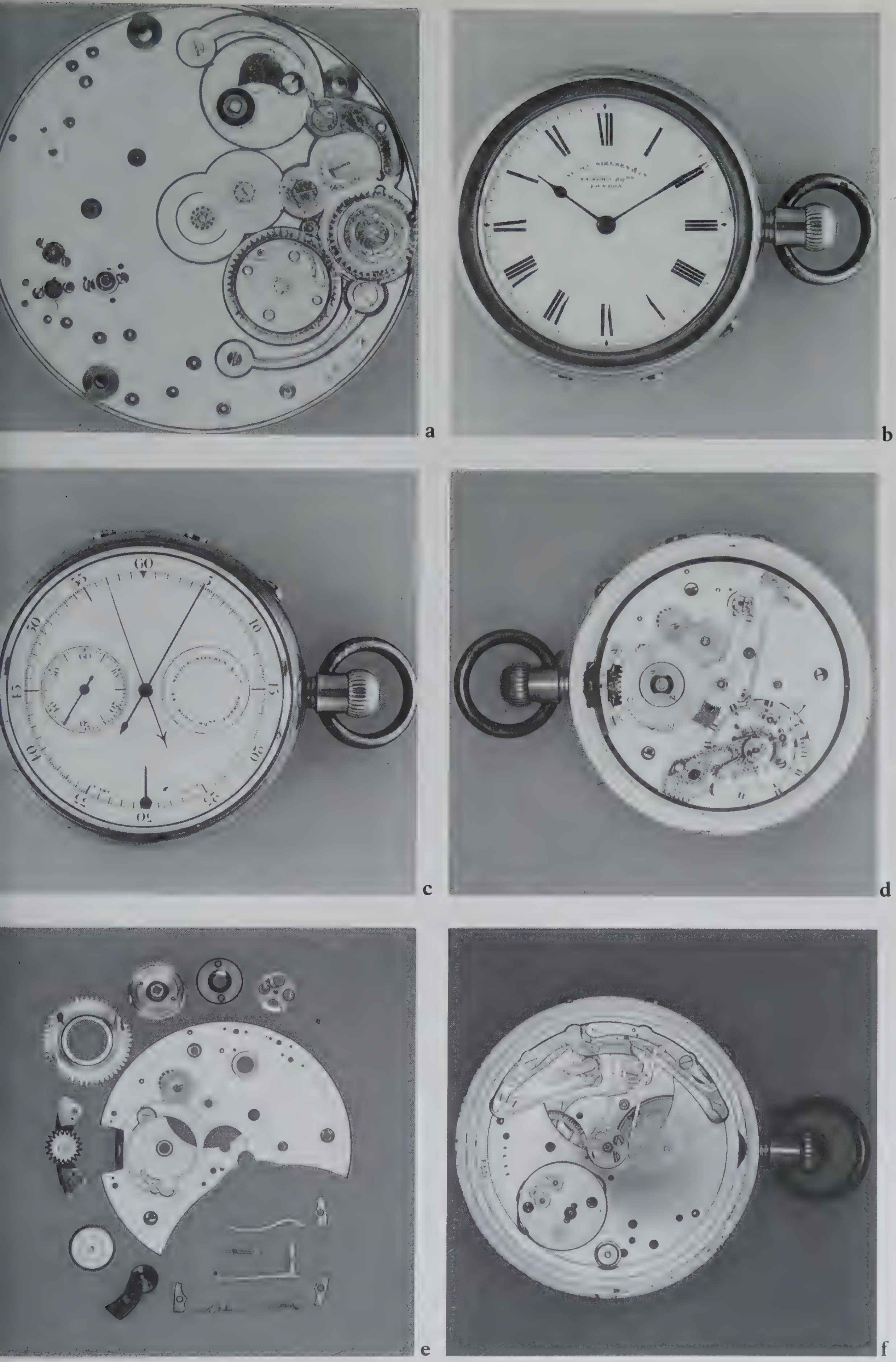
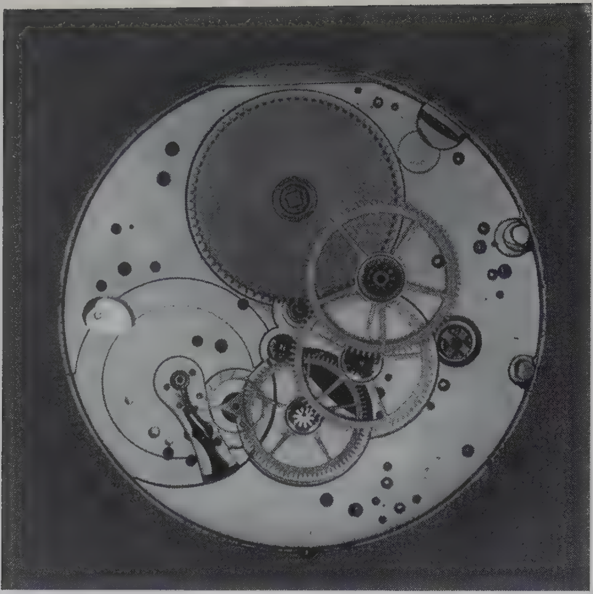


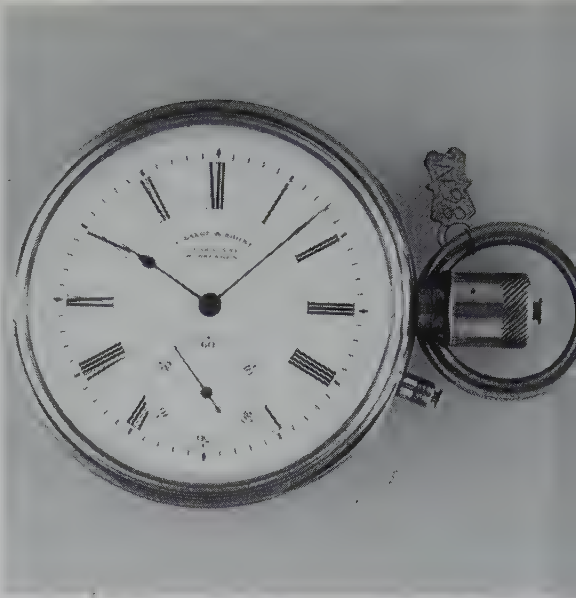
Plate 101

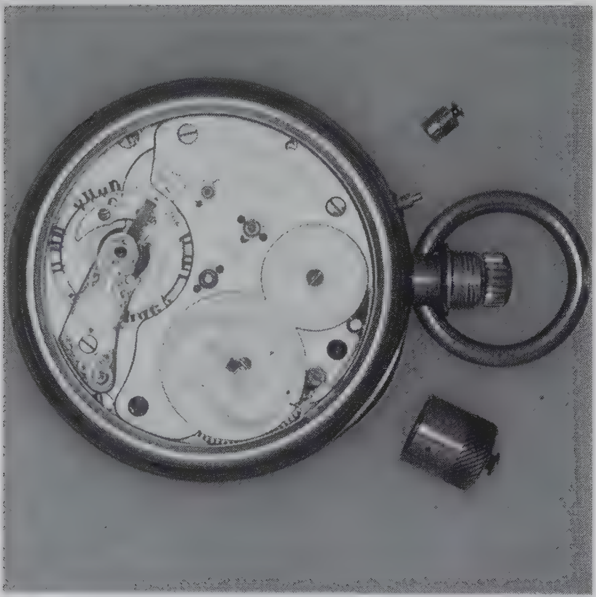
a. Cat. no. 138.
b. Cat. no. 139, the first dial.
c. Cat. no. 139, the second dial.
d. Cat. no. 139, the 'back' of the movement.
e. Cat. no. 139, the backplate with many parts removed.
f. Cat. no. 139, the 'front' plate.

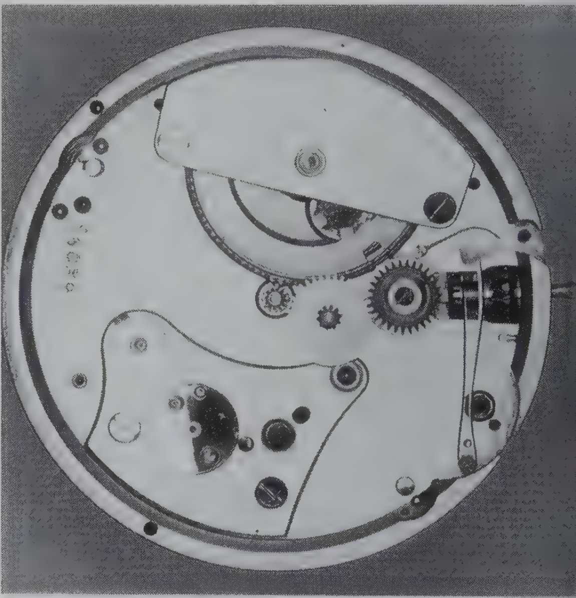
Plate 102

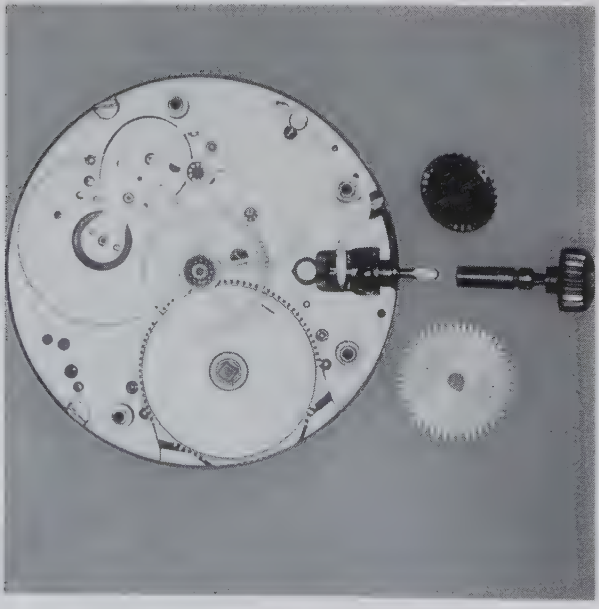
a. Cat. no. 139.
b. Cat. no. 140.
c. Cat. no. 140.
d. Cat. no. 140.
e. Cat. no. 140.
f. Cat. no. 140.

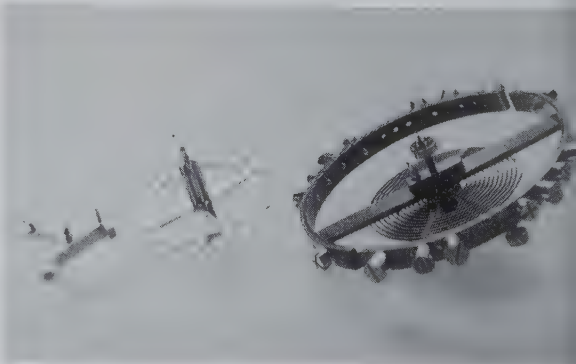

a

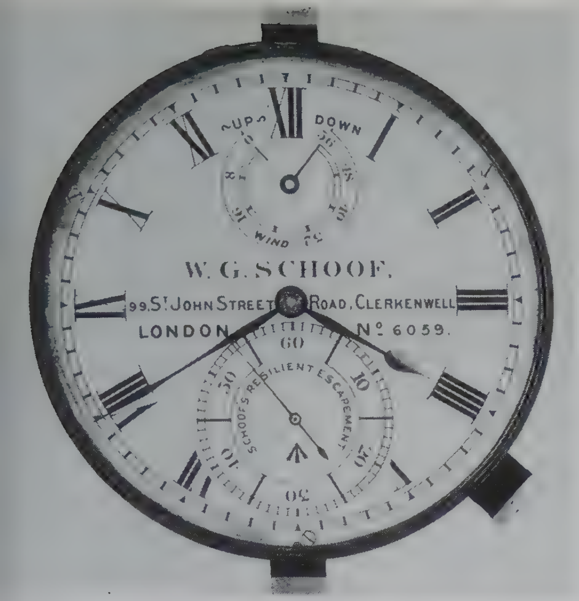

b


c

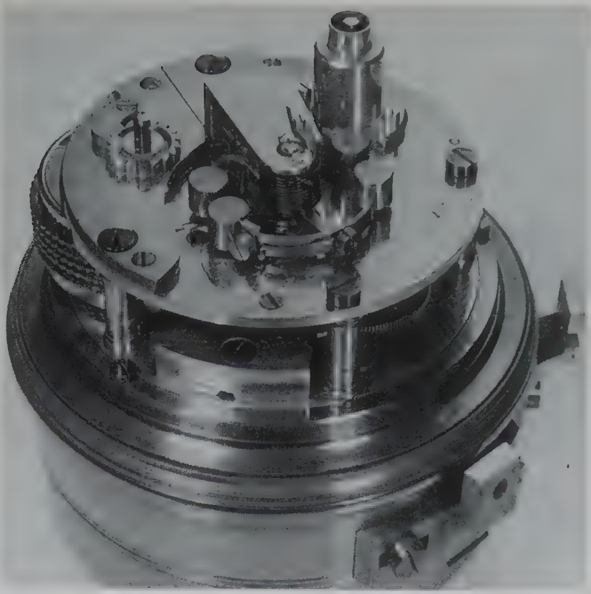

d


e

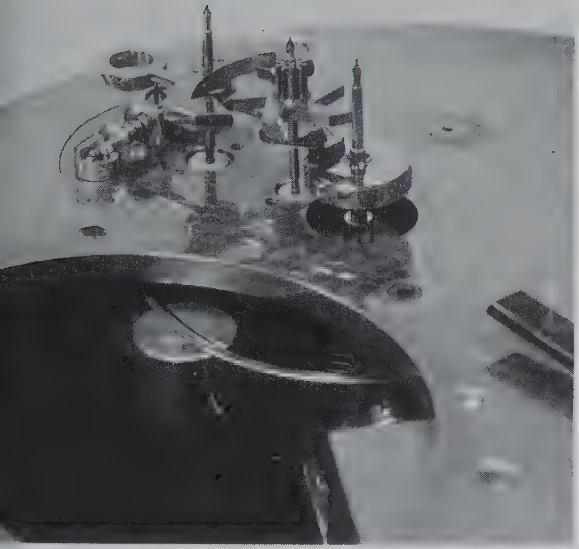

f


UP
DOWN
WIND
W. G. SCHOOF.
99. St JOHN STREET ROAD, CLERKENWELL
LONDON
No 6059.
SCHOOF'S RESILIENT ESCAPEMENT

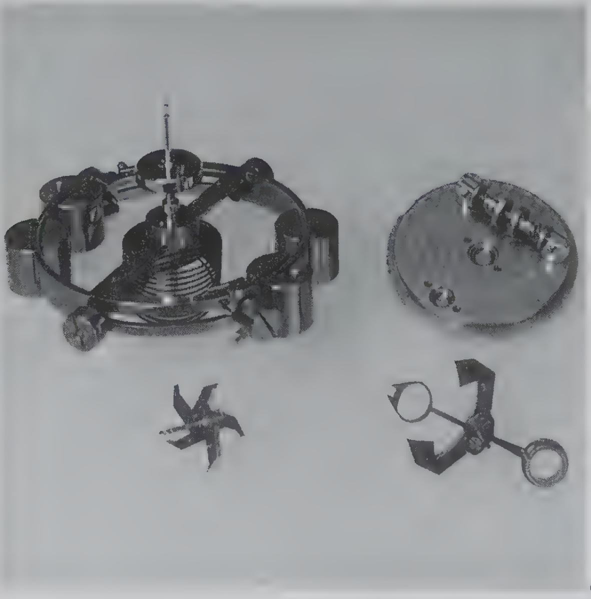
a



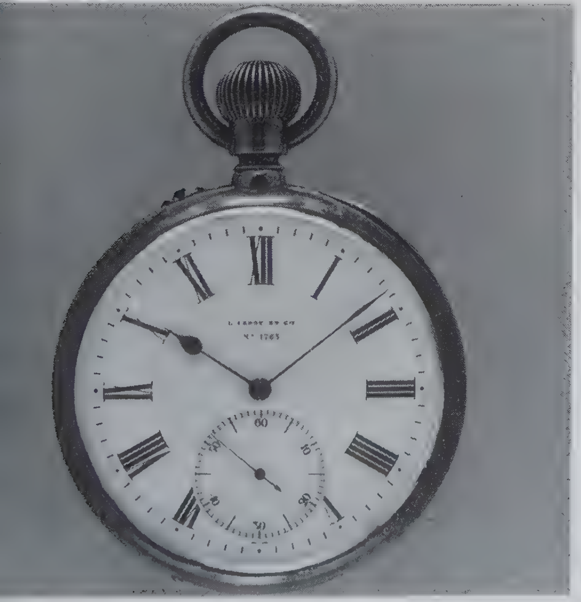
b



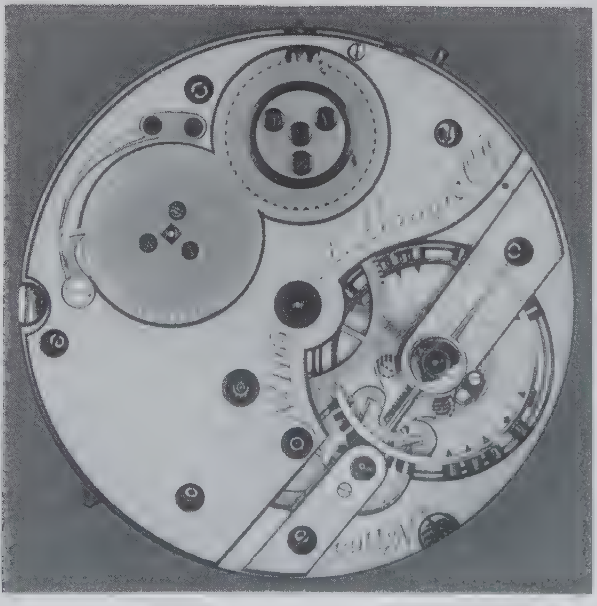
c



d



e



f

Plate 103

a. Cat. no. 141.
b. Cat. no. 141.
c. Cat. no. 141.
d. Cat. no. 141, the balance, escapement and resilient banking.
e. Cat. no. 142.
f. Cat. no. 142.

Plate 104

a. Cat. no. 142.
b. Cat. no. 142.
c. Cat. no. 143.
d. Cat. no. 143.
e. Cat. no. 143.
f. Cat. no. 143, the chronograph plate.

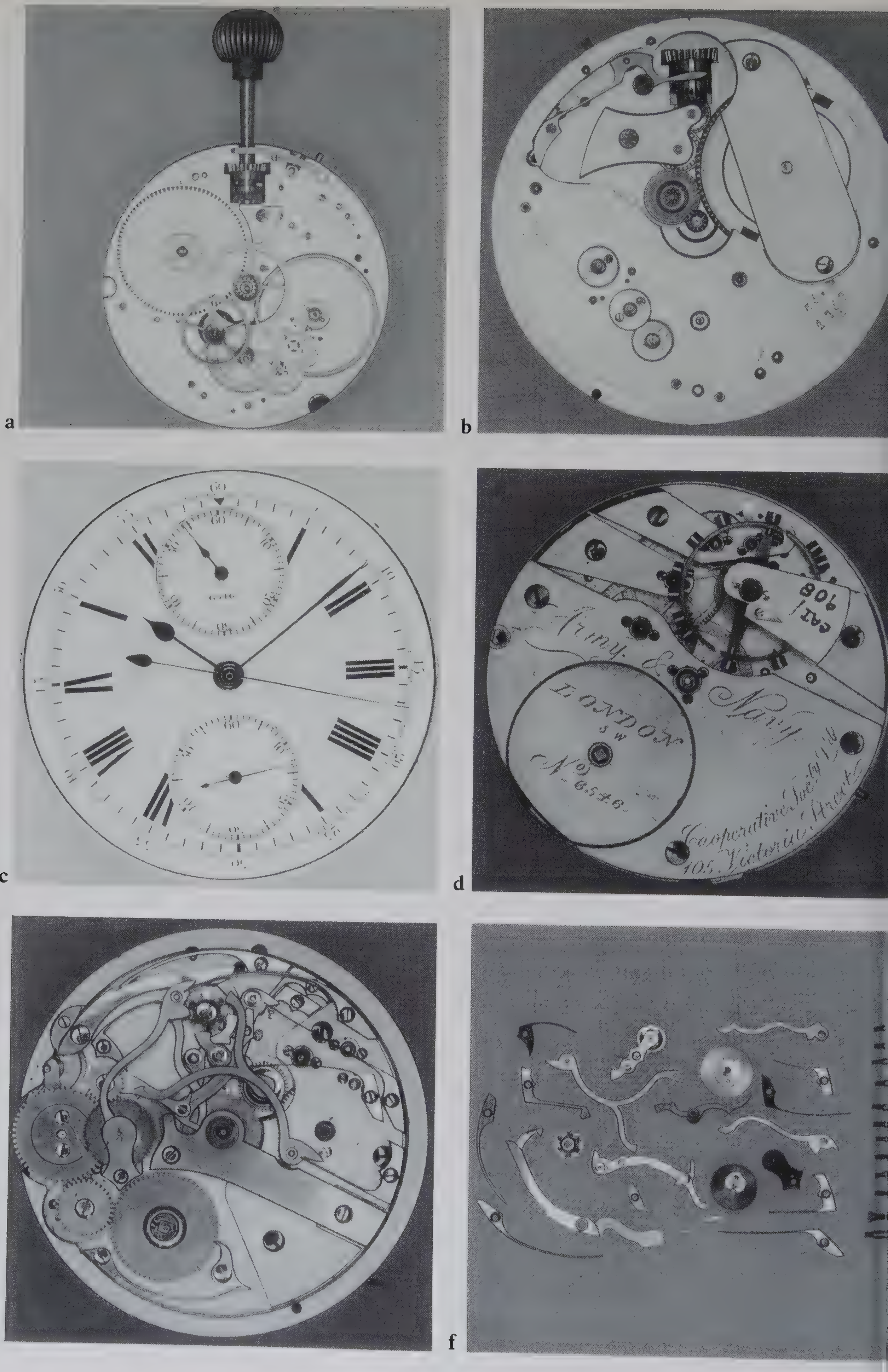
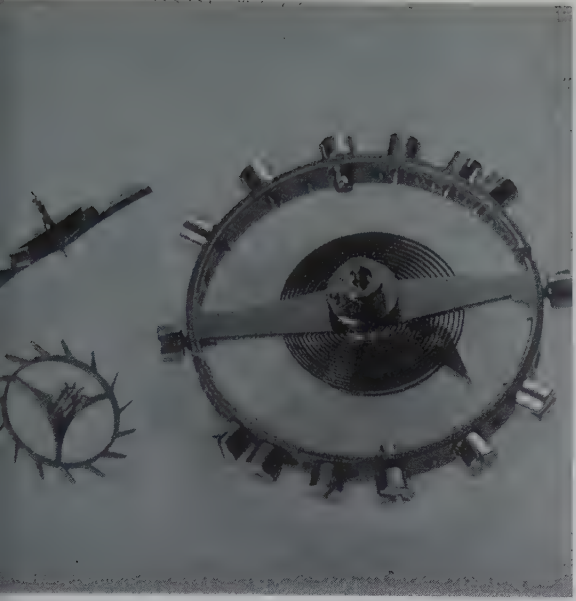
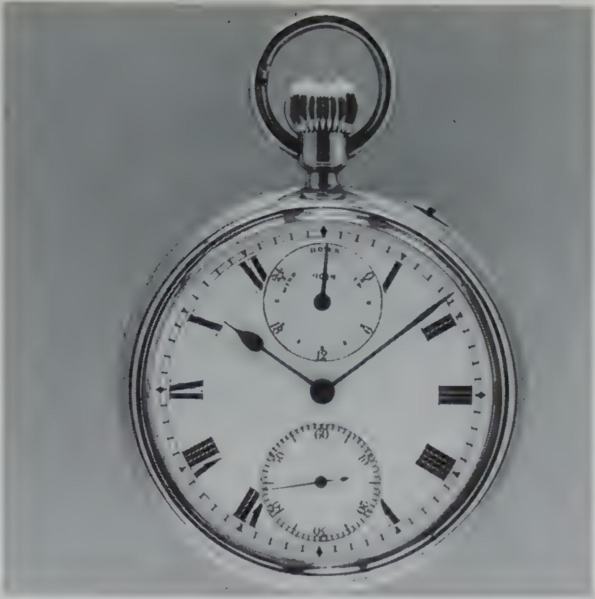

a
b
c
d
Army & Navy
LONDON
SW
No 6546
Cooperative Socty Ld
105 Victoria Street
CAL 108
e
f

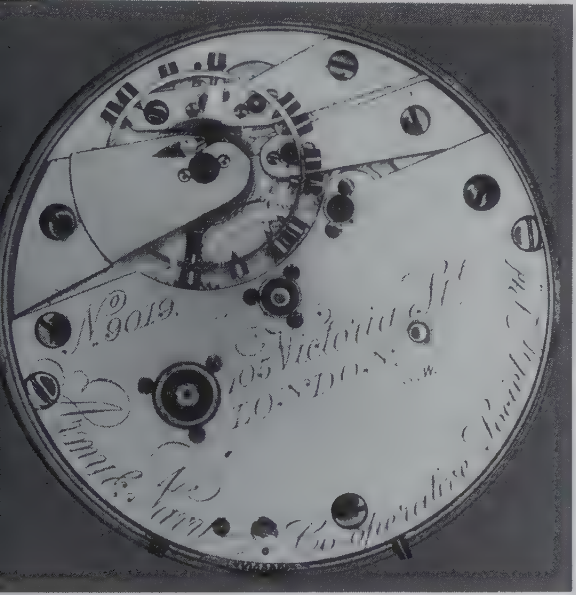
Plate 105

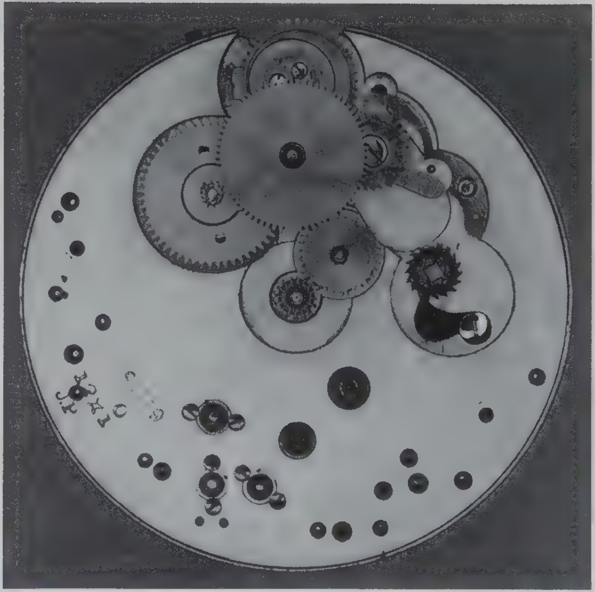
a. Cat. no. 143.
b. Cat. no. 144.
c. Cat. no. 144.
d. Cat. no. 144, the keyless work, the up-and-down work beneath the dial.
e. Cat. no. 145.
f. Cat. no. 145.

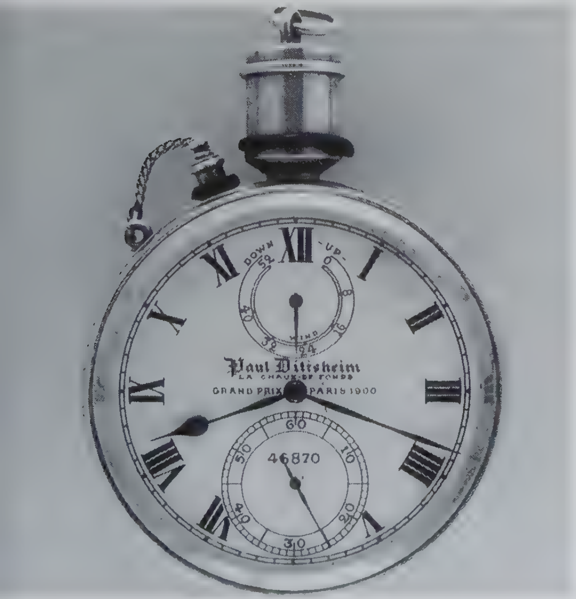

a



b


No 9019.
105 Victoria St
LONDON S.W.
Army & Navy Co-operative Society Ld
c


d


DOWN
UP
WIND
Paul Ditisheim
LA CHAUX-DE-FONDS
GRAND PRIX PARIS 1900
46870
e

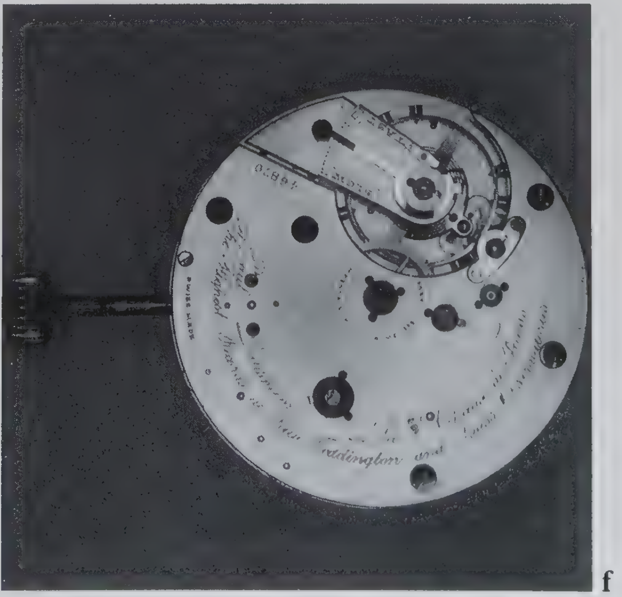
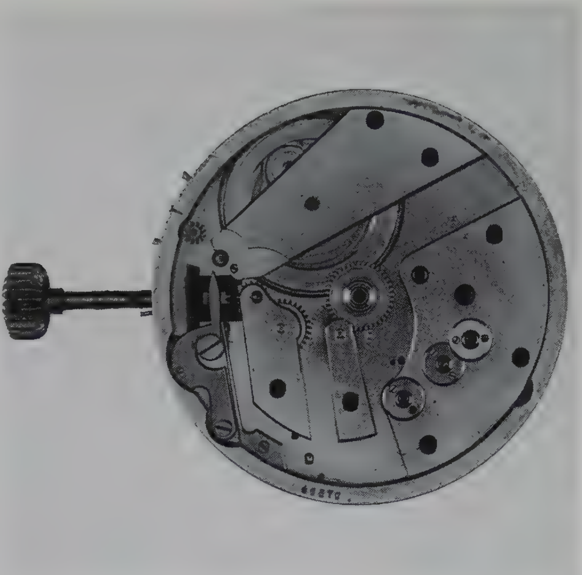
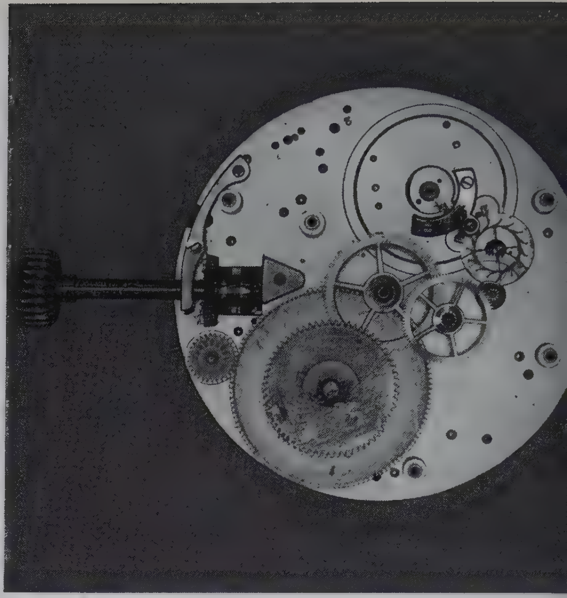
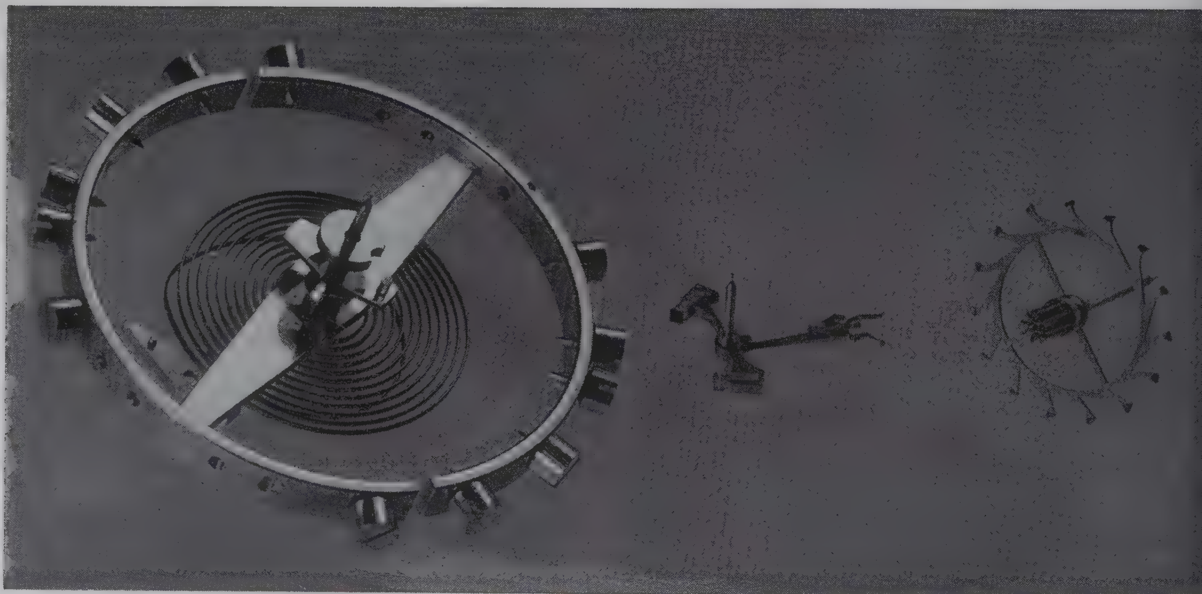

46870
SWISS MADE
Teddington
f

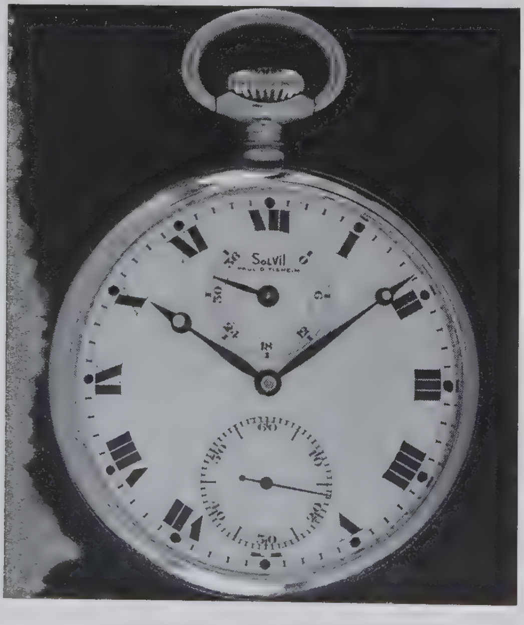
Plate 106

a. Cat. no. 145.
b. Cat. no. 145, the underside of the backplate.
c. Cat. no. 145, escapement.
d. Cat. no. 146.
e. Cat. no. 146.


a


b


c



d

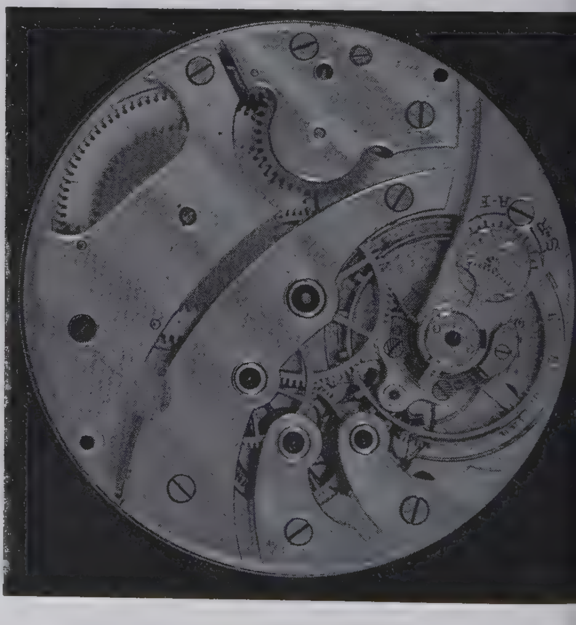
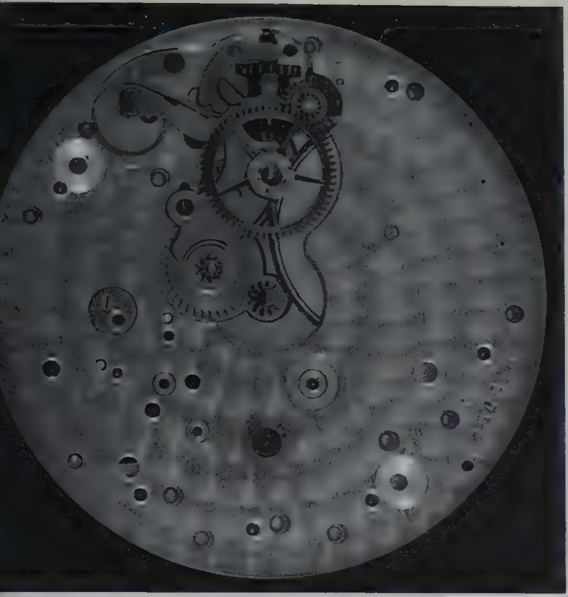
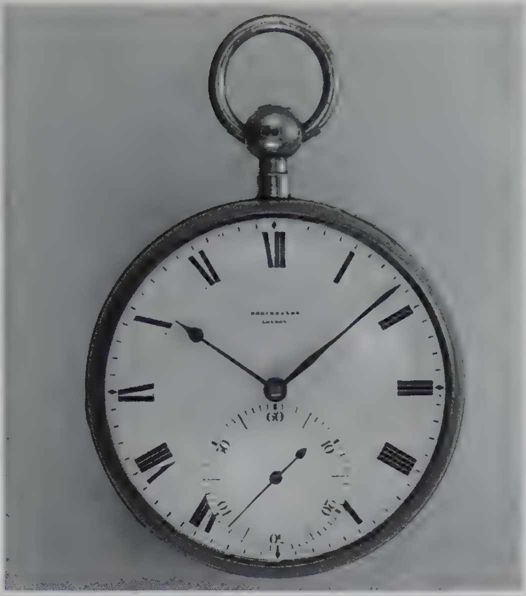
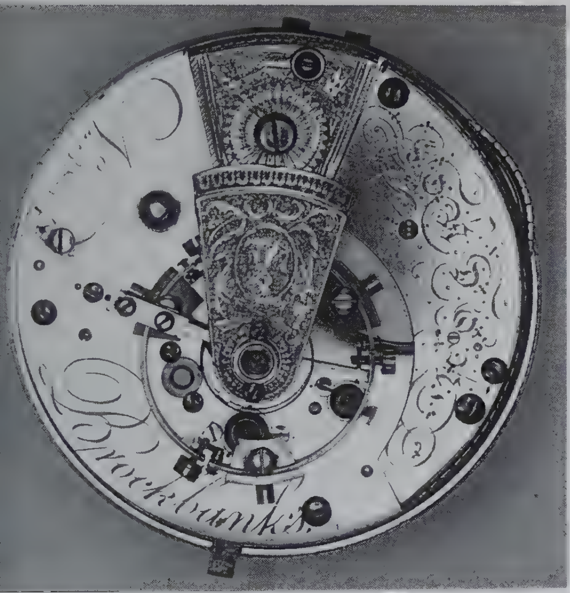

e

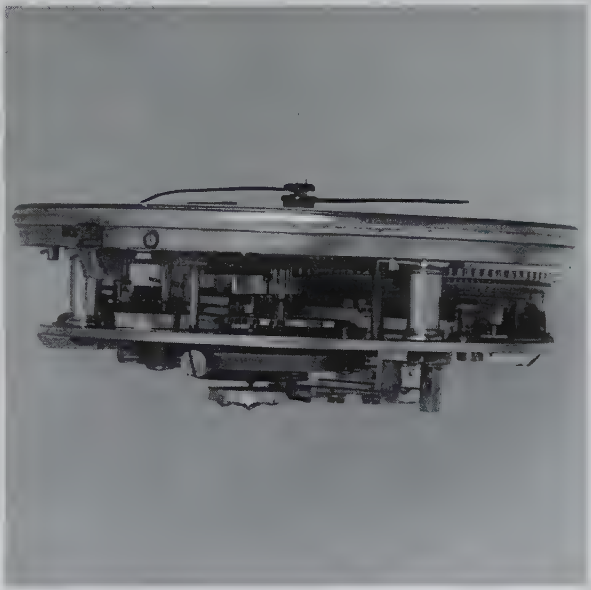
Plate 107

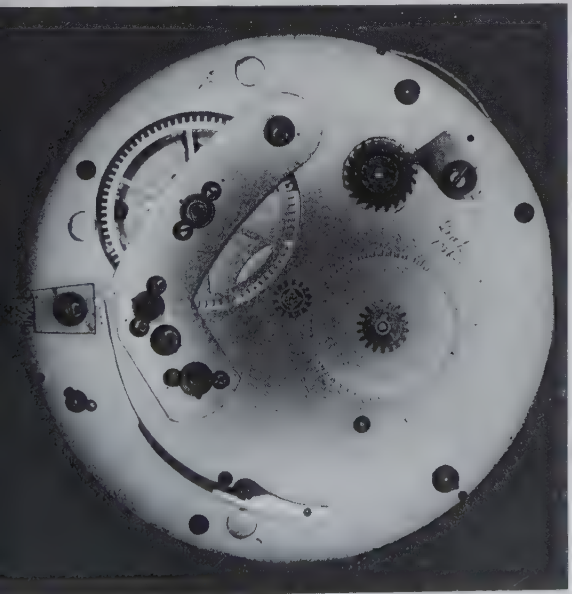
a. Cat. no. 146.
b. Cat. no. 147.
c. Cat. no. 147.
d. Cat. no. 147.
e. Cat. no. 147.
f. Cat. no. 147.


a


b


Brockbanks
c


d


e

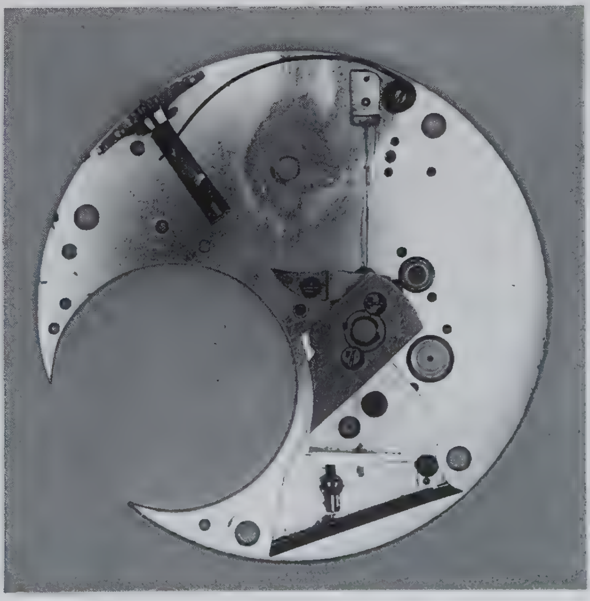
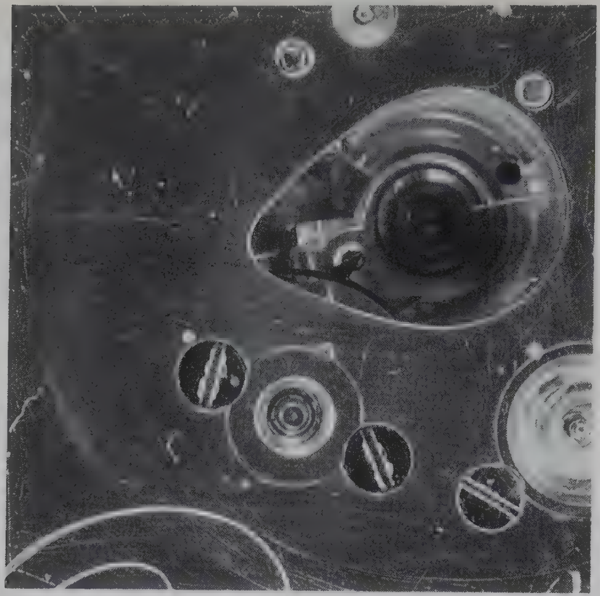
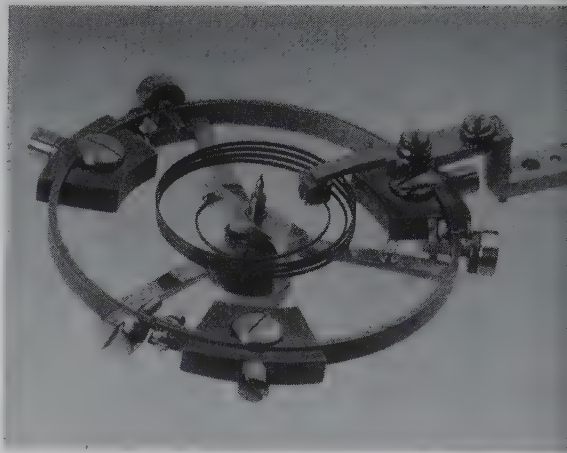
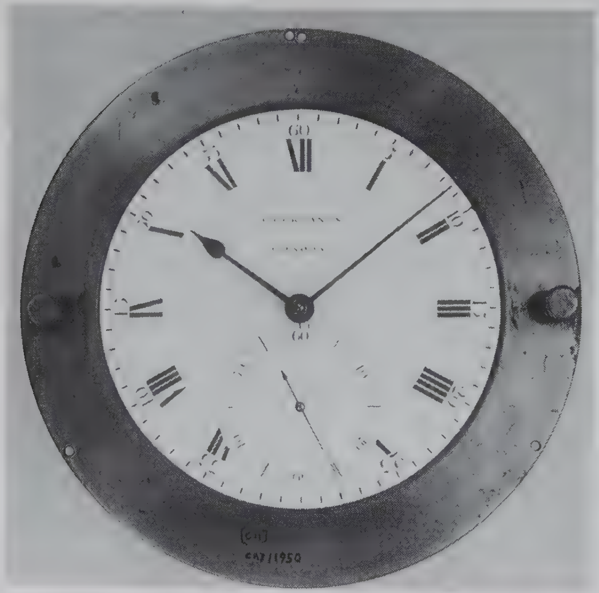

f

Plate 108

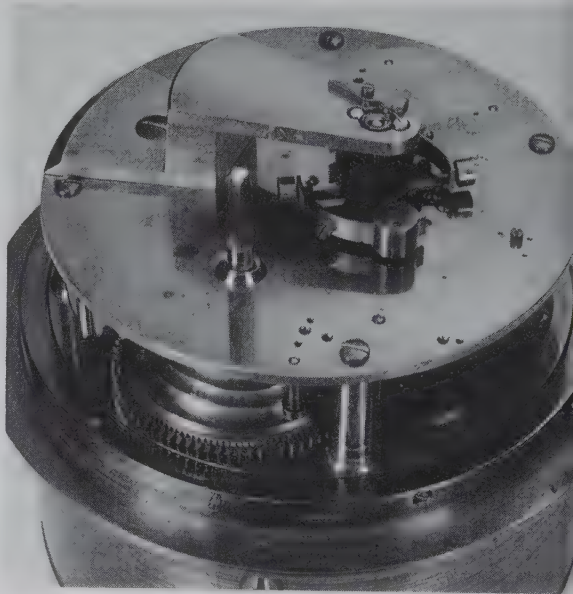
a. Cat. no. 147. Through the hole the detent and passing spring are visible.
b. Cat. no. 147.
c. Cat. no. 148.
d. Cat. no. 148.
e. Cat. no. 149.
f. Cat. no. 149.

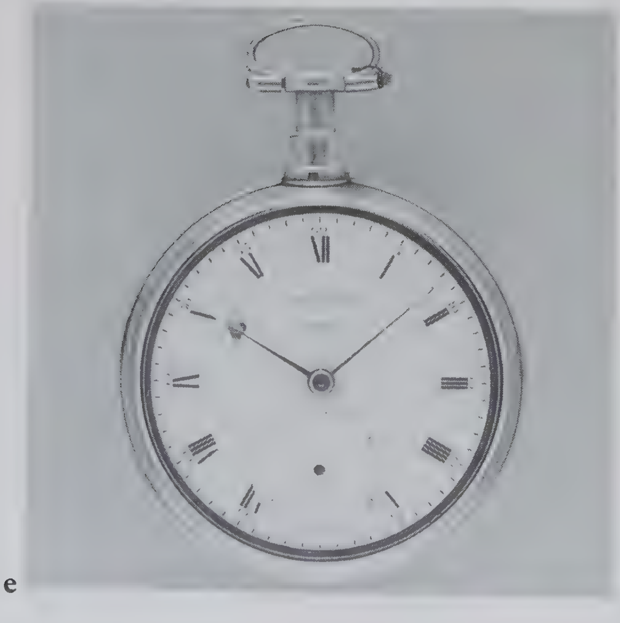

a

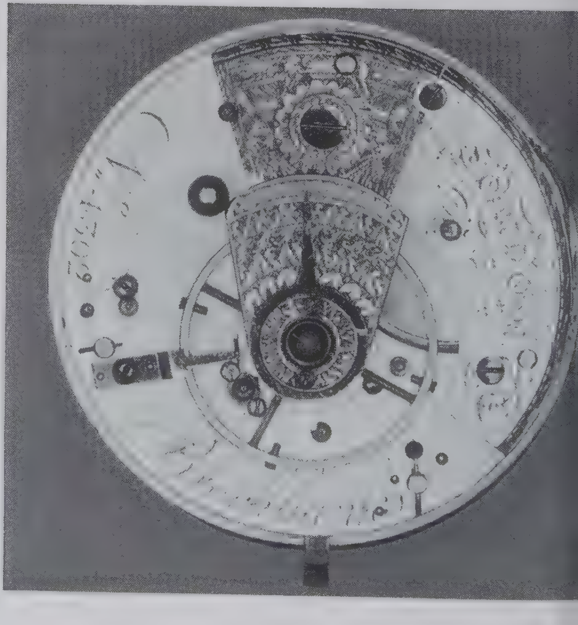

b



c


d


e


f

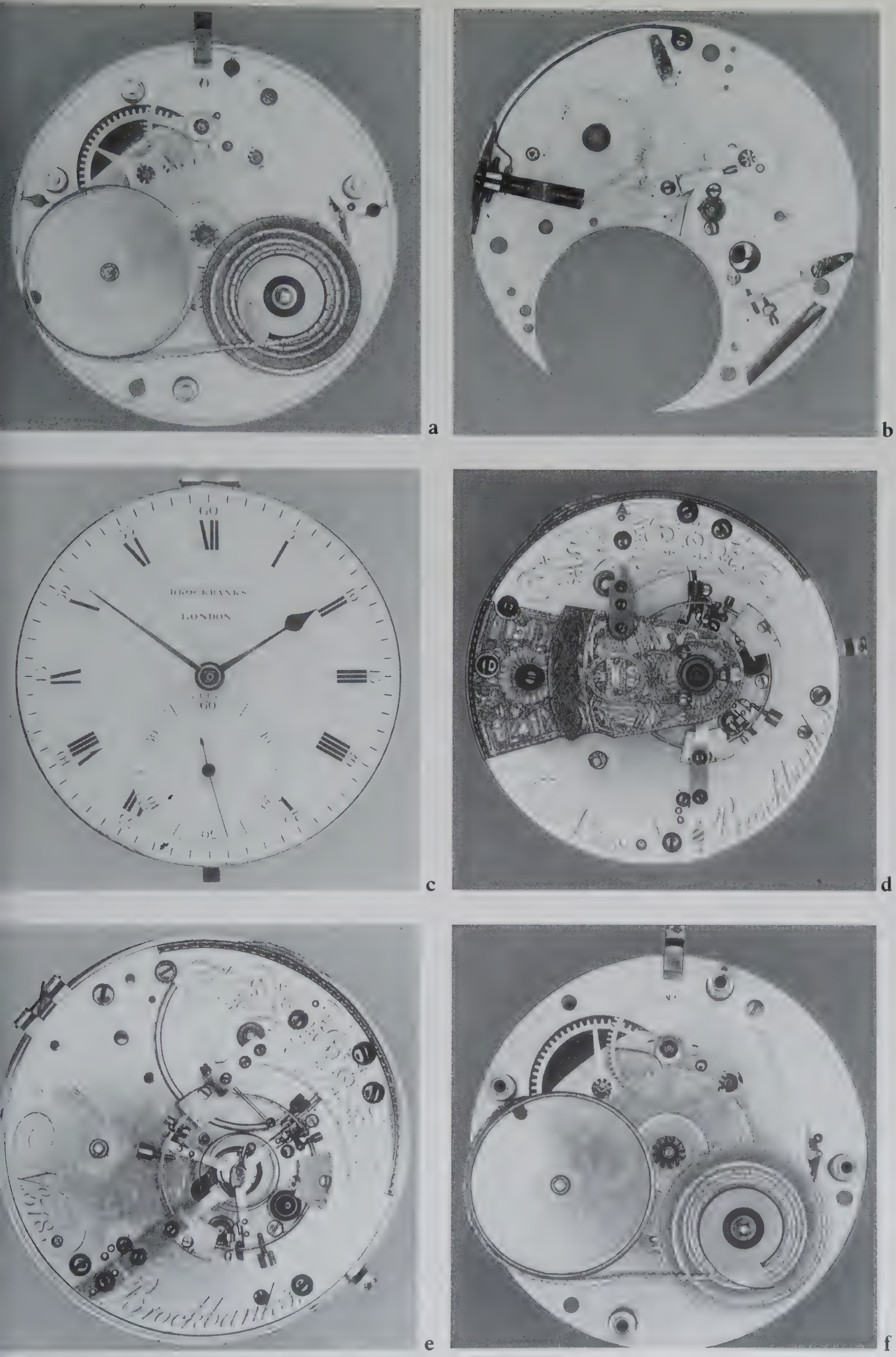
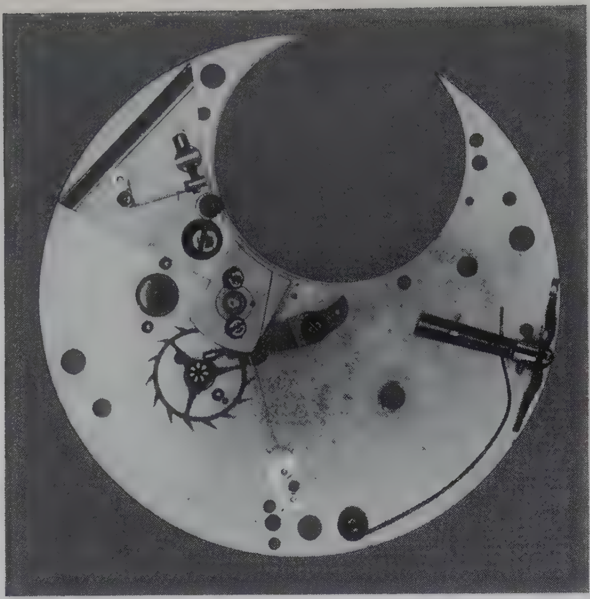

a
b
BROCKBANKS
LONDON
c
d
e
Brockbanks
f

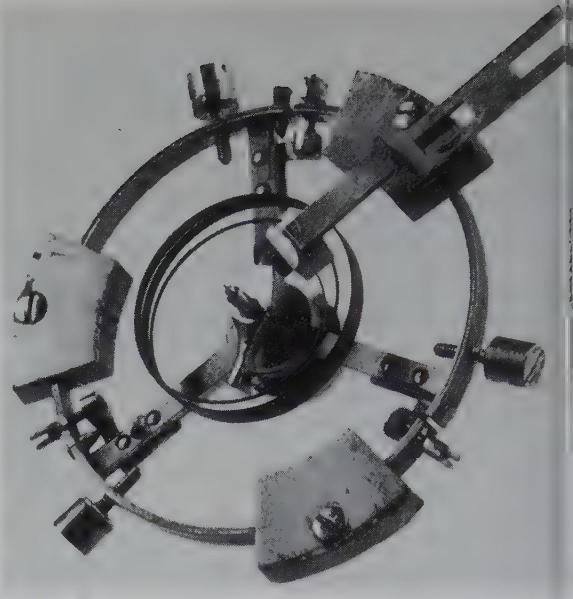
Plate 109

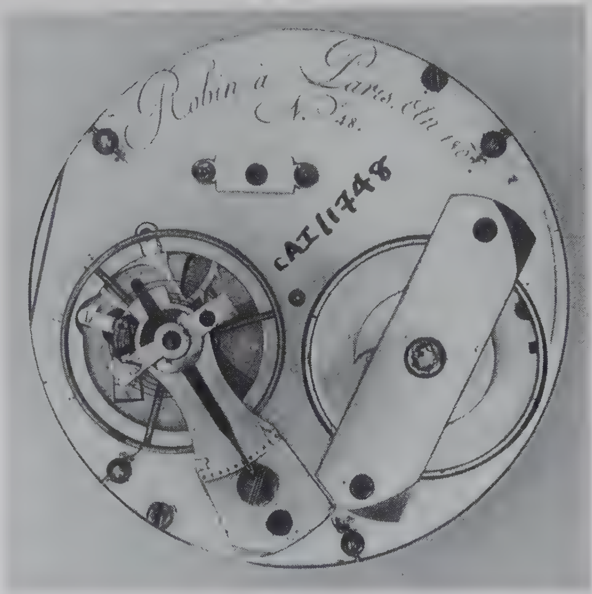
a. Cat. no. 149.
b. Cat. no. 149.
c. Cat. no. 150.
d. Cat. no. 150. The steel cock at the top of the movement in the illustration supports the amplitude limiting device.
e. Cat. no. 150, the balance cock removed revealing the amplitude limiting device.
f. Cat. no. 150.

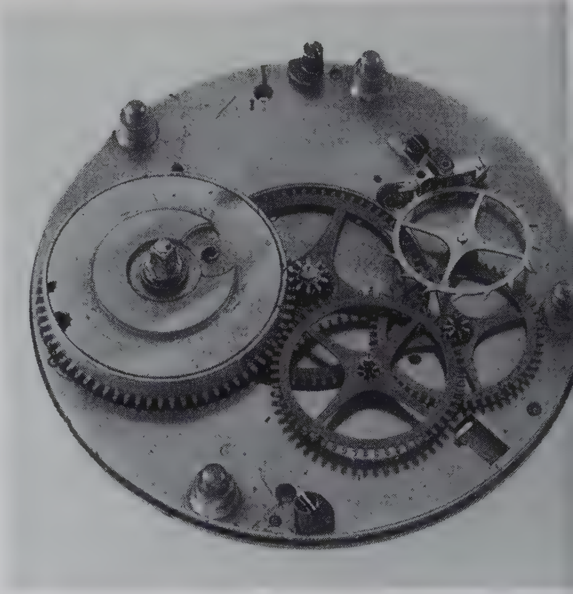
Plate 110

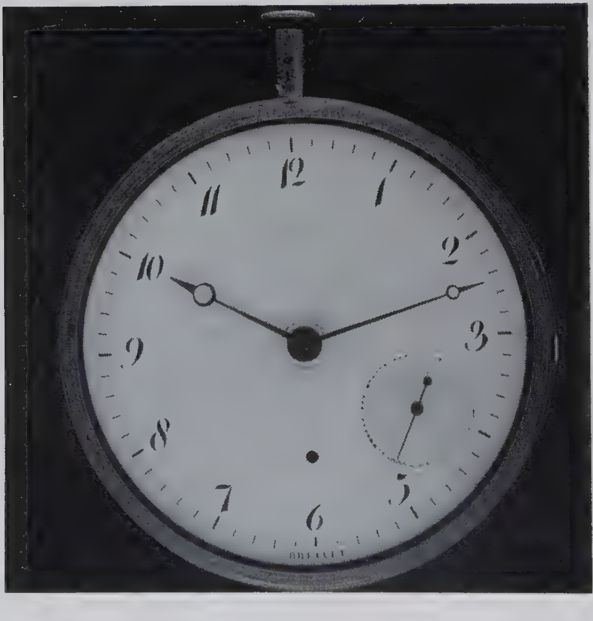
a. Cat. no. 150.
b. Cat. no. 150.
c. Cat. no. 151. This watch has no dial.
d. Cat. no. 151.
e. Cat. no. 152.
f. Cat. no. 152.


a


b


Robin à Paris
CAI 11748
c


d


12
1
2
3
5
6
7
8
9
10
11
BREGUET
e

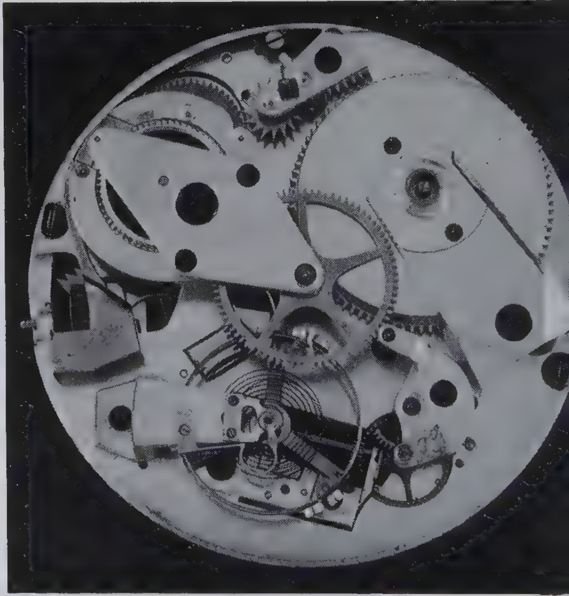
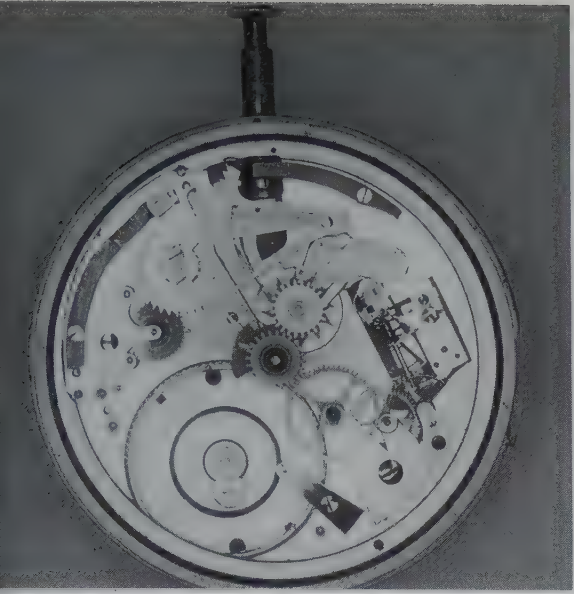
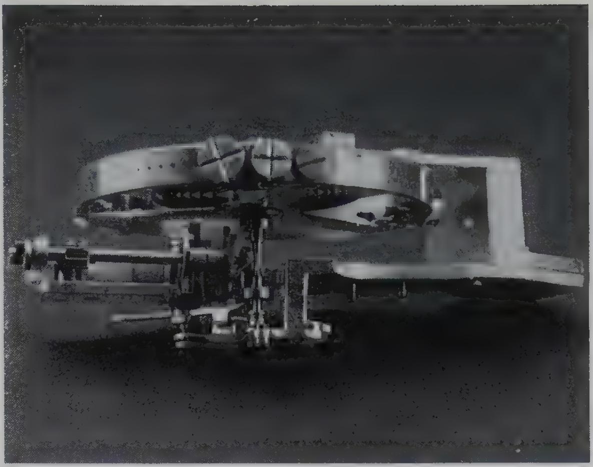
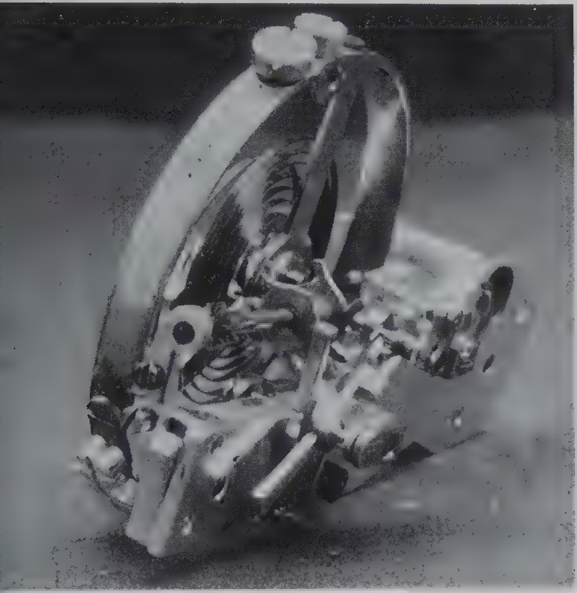

f

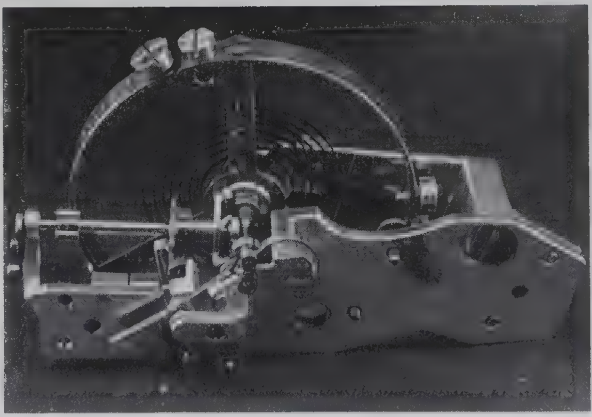
Plate 111

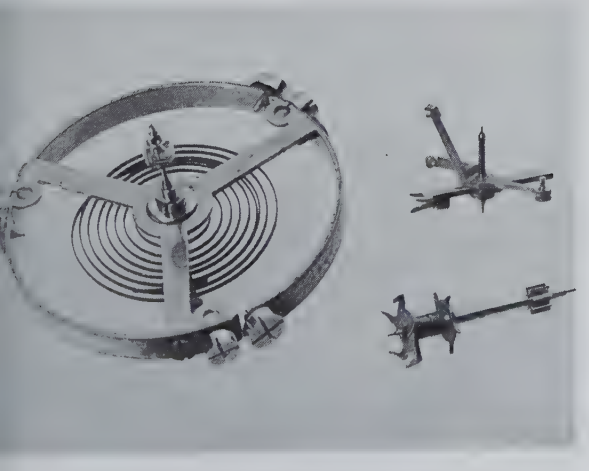
a. Cat. no. 152.
b. Cat. no. 152.
c. Cat. no. 152.
d. Cat. no. 152.
e. Cat. no. 152.
f. Cat. no. 153.
The secret signature has been wax-filled to make it visible.


a


b


c


d


e

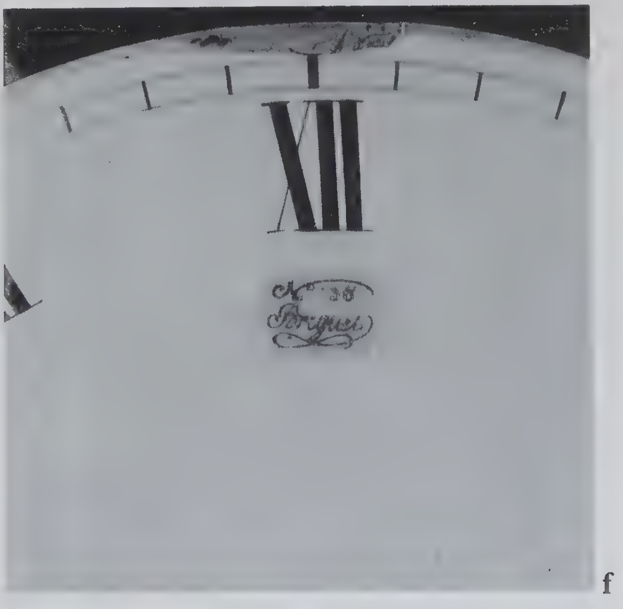
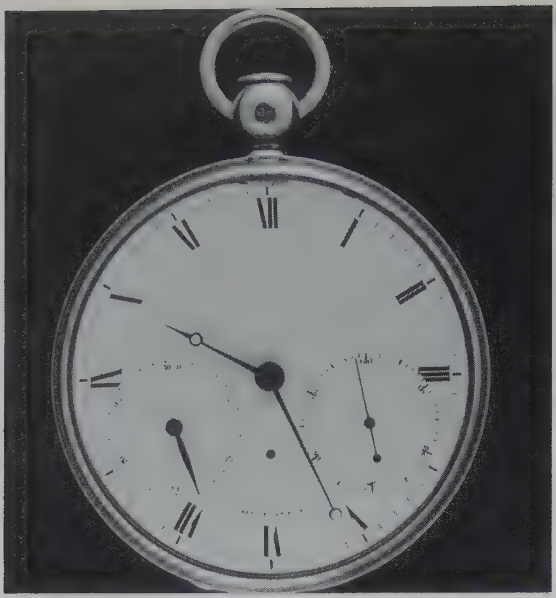
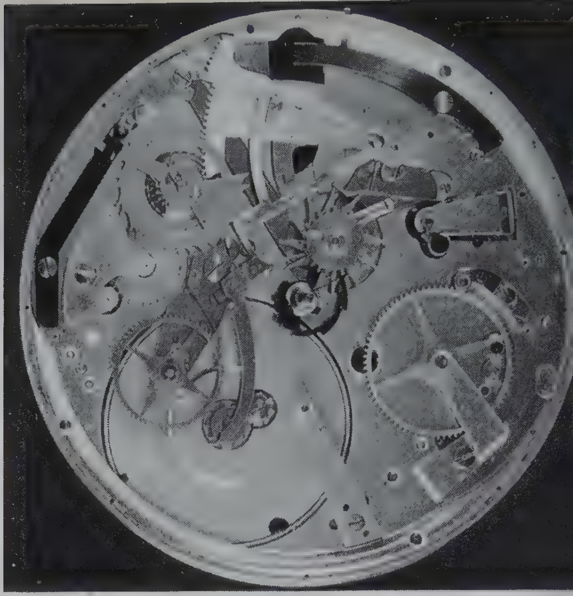
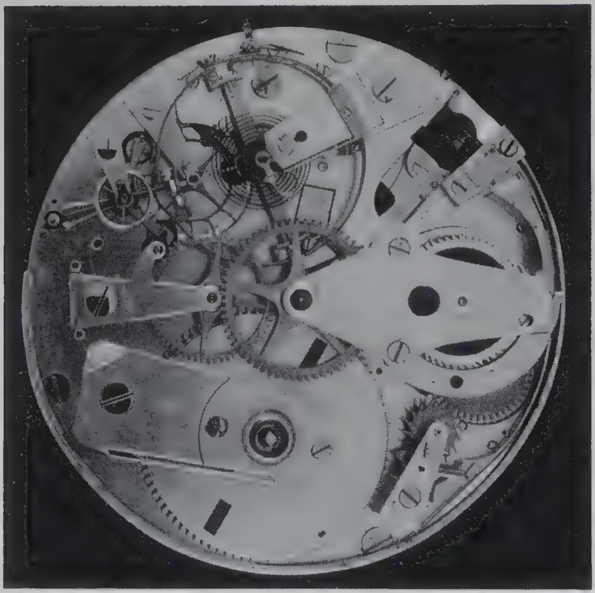

XII
No 38
Breguet
f

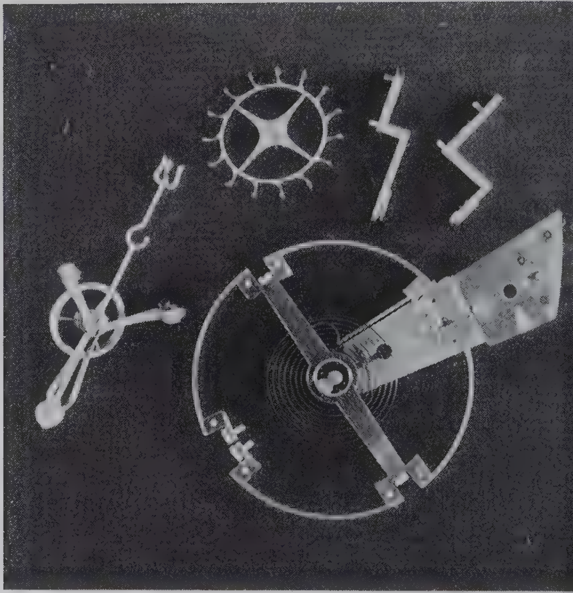
Plate 112

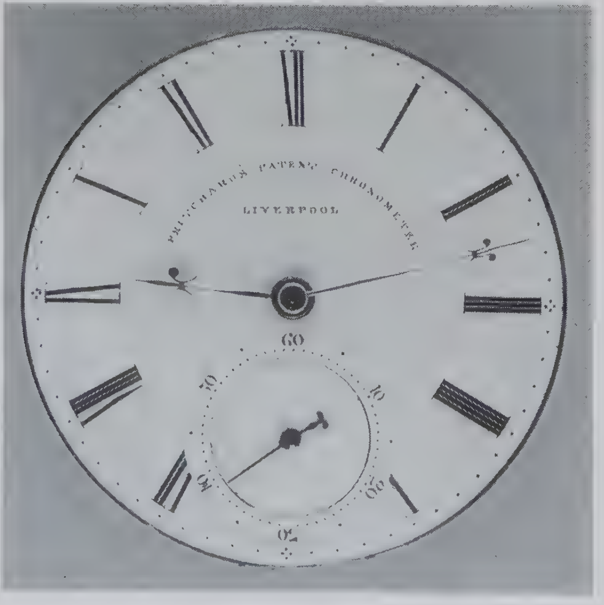
a. Cat. no. 153.
b. Cat. no. 153.
c. Cat. no. 153.
d. Cat. no. 153.
e. Cat. no. 154.
f. Cat. no. 154.


a


b


c


d


PRITCHARDS PATENT CHRONOMETER
LIVERPOOL
60
10
20
30
50
e

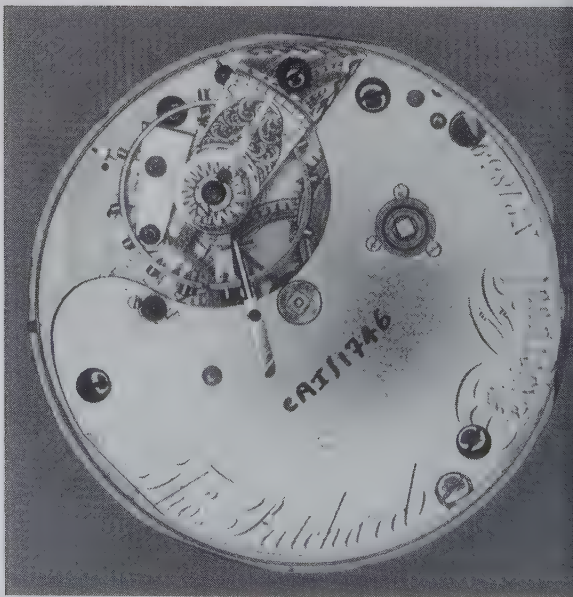
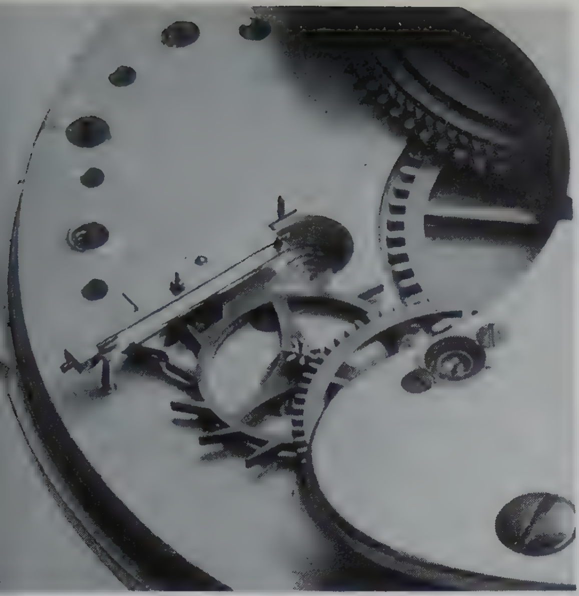
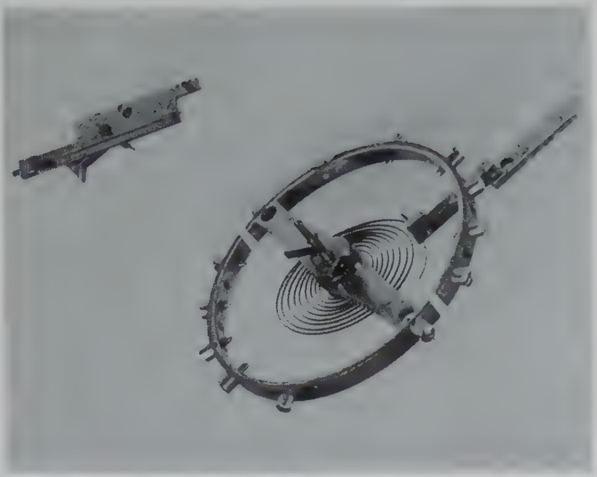

CA1/1746
Thos Pritchard
f

Plate 113

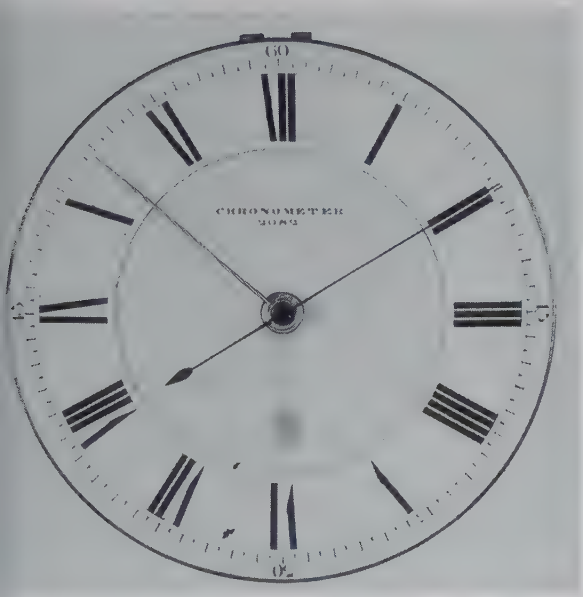
a. Cat. no. 154.
b. Cat. no. 154.
c. Cat. no. 155.
d. Cat. no. 155.
e. Cat. no. 155.
f. Cat. no. 155.



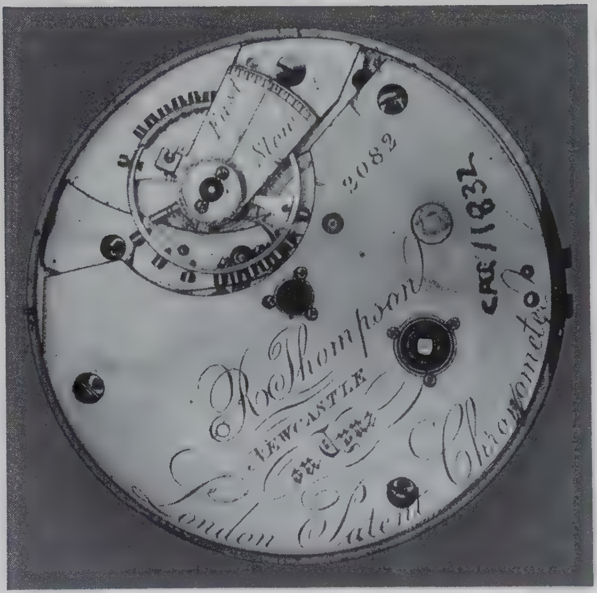
a



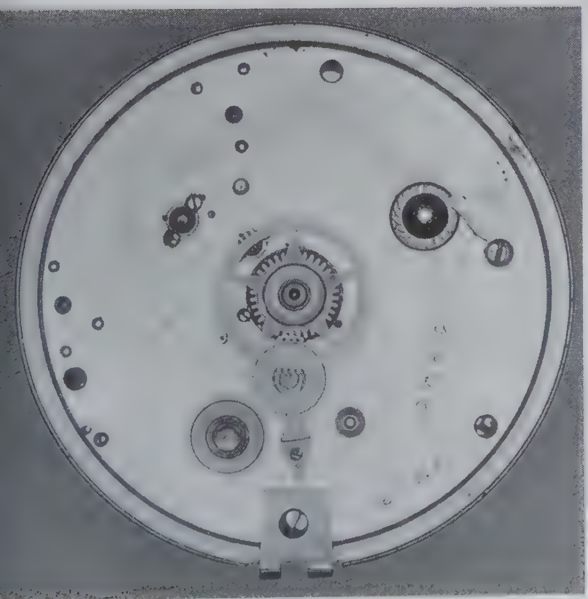
b


60
CHRONOMETER
2082

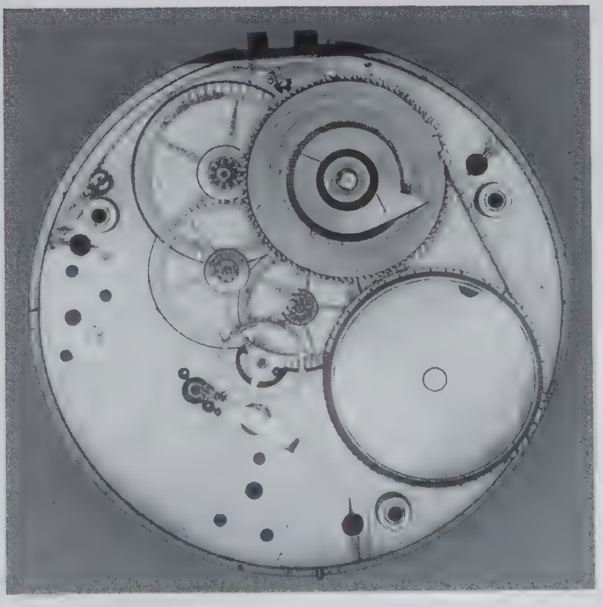
c


Fast
Slow
2082
CAT/1183L
R. Thompson
NEWCASTLE
on Tyne
No
London Patent Chronometer

d



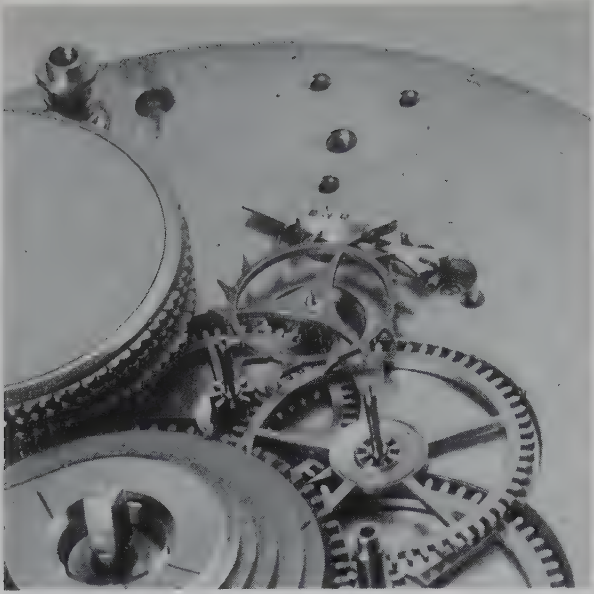
e

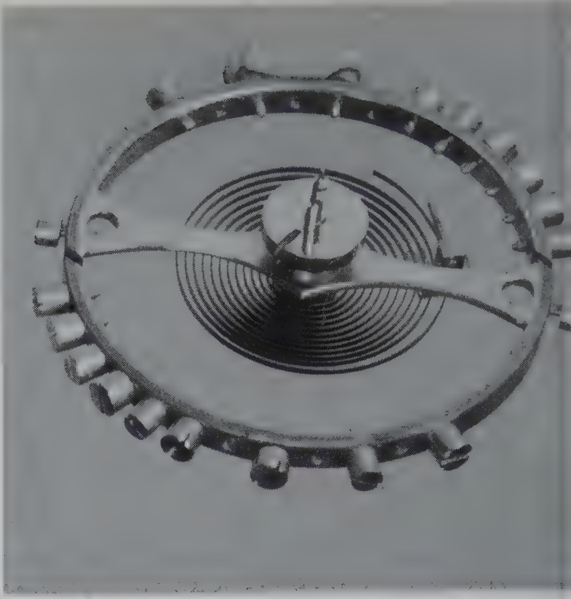


f

Plate 114

a. Cat. no. 155.
b. Cat. no. 155.
c. Cat. no. 156.
d. Cat. no. 156.
e. Cat. no. 156.
f. Cat. no. 156.


a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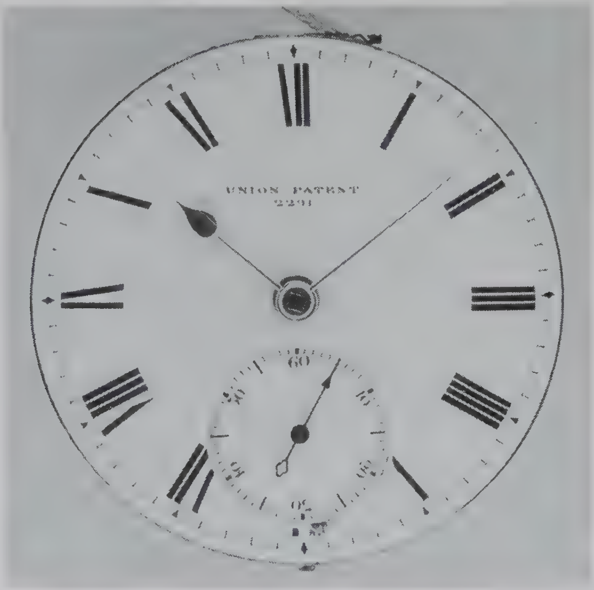
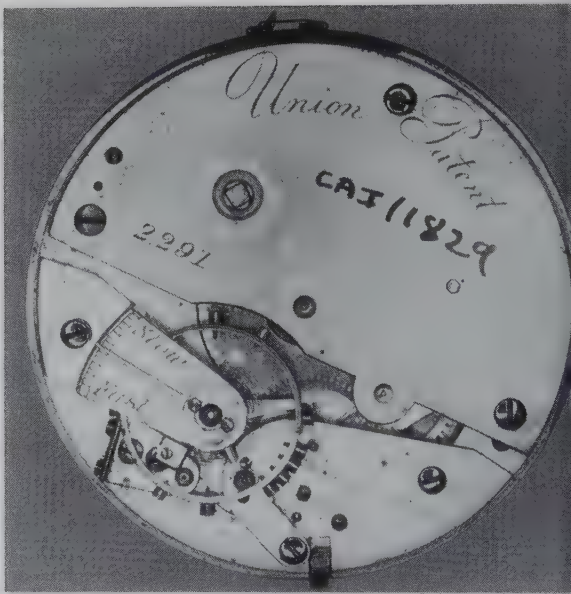
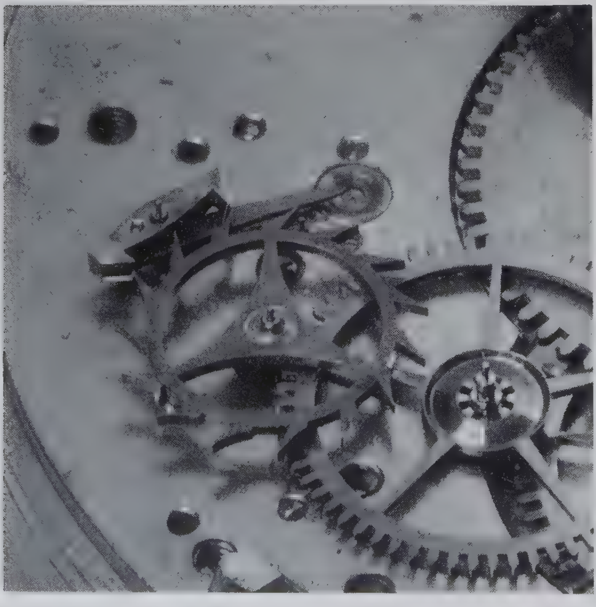

UNION PATENT
2291
60
c


Union Patent
CAJ 11829
2291
Slow
Fast
d


e

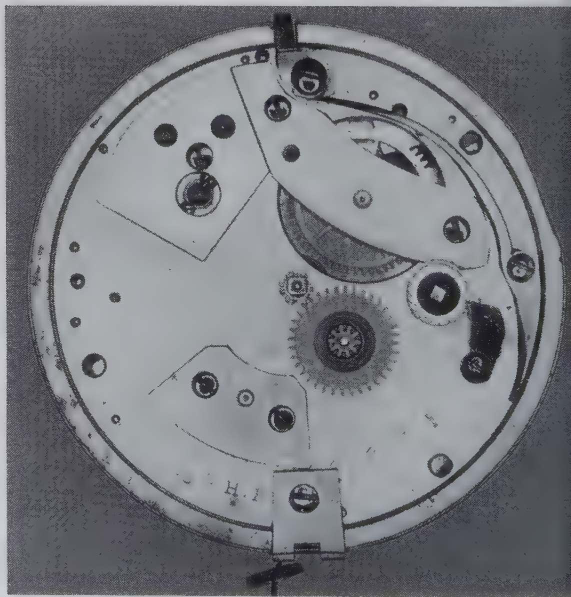
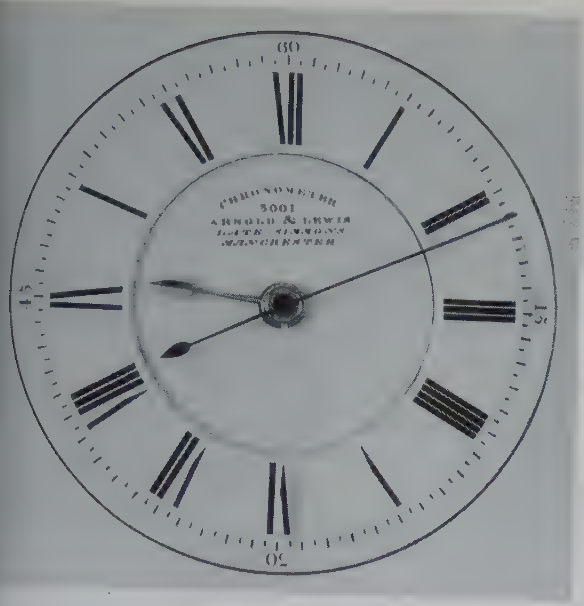
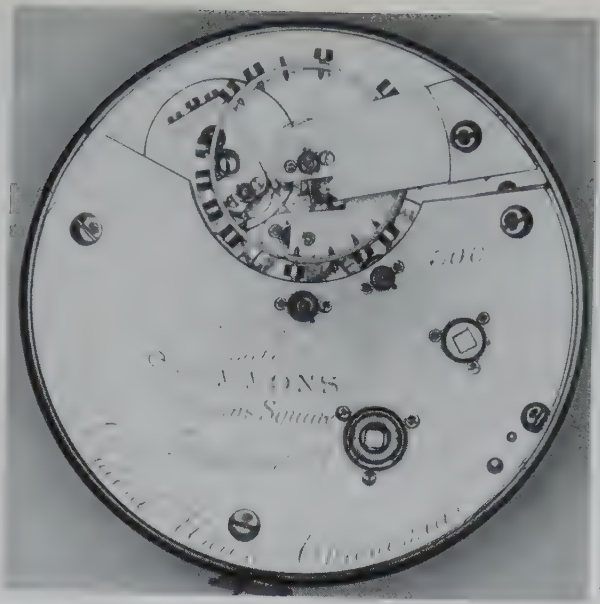

f

Plate 115

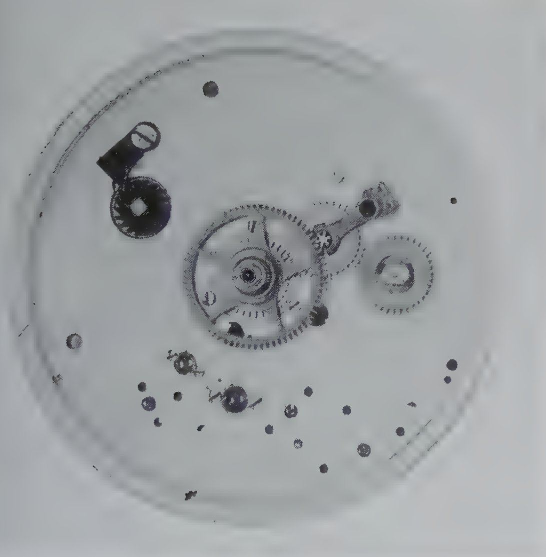
a. Cat. no. 157.
b. Cat. no. 157.
c. Cat. no. 157.
d. Cat. no. 157.
e. Cat. no. 158.
f. Cat. no. 158.


CHRONOMETER
3001
ARNOLD & LEWIS
LATE SIMMONS
MANCHESTER
60
15
30
45

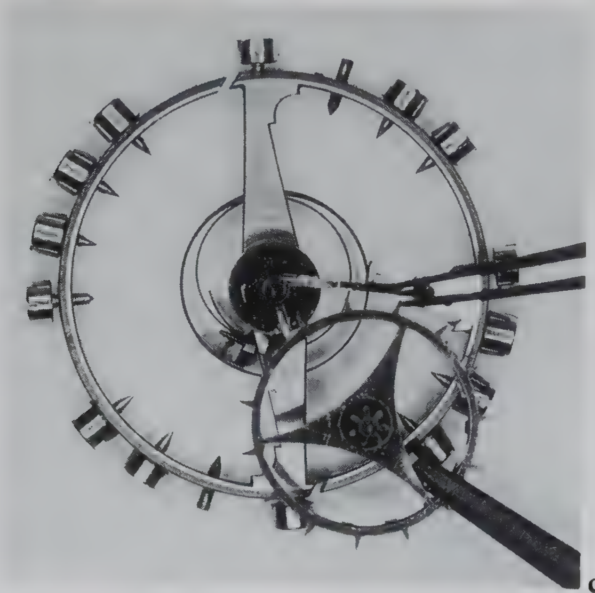
a


SIMONS
Square

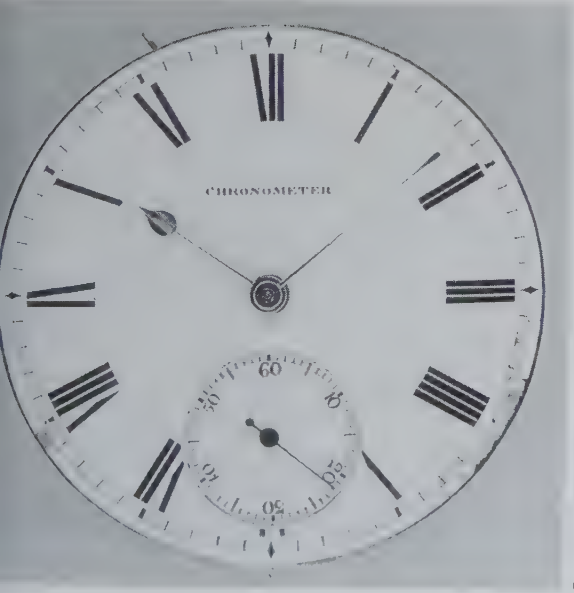
b



c



d


CHRONOMETER
60
10
20
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40
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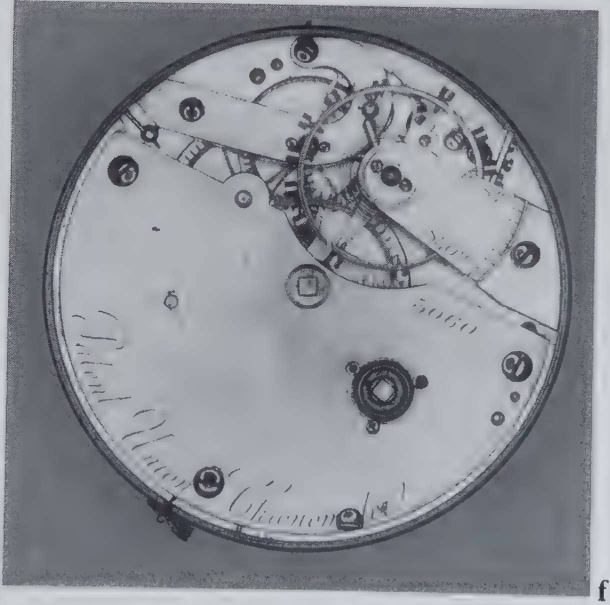
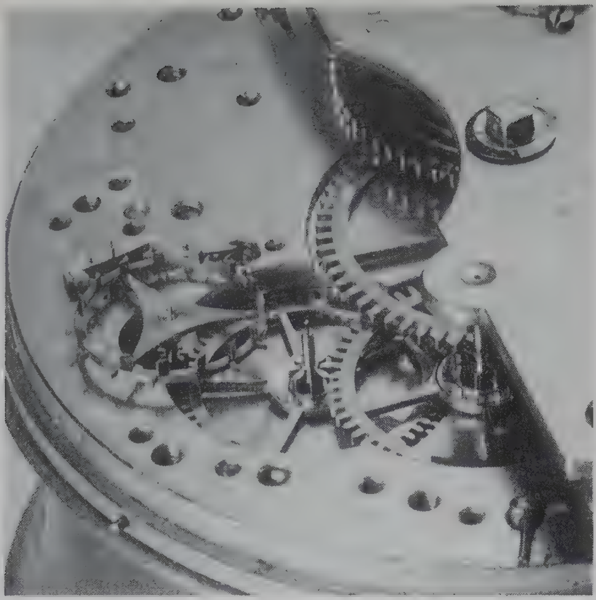
e

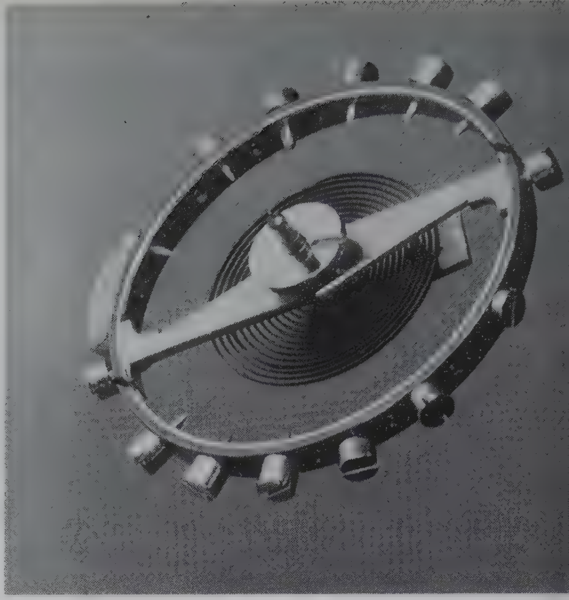

5060
Patent Lever Chronometer

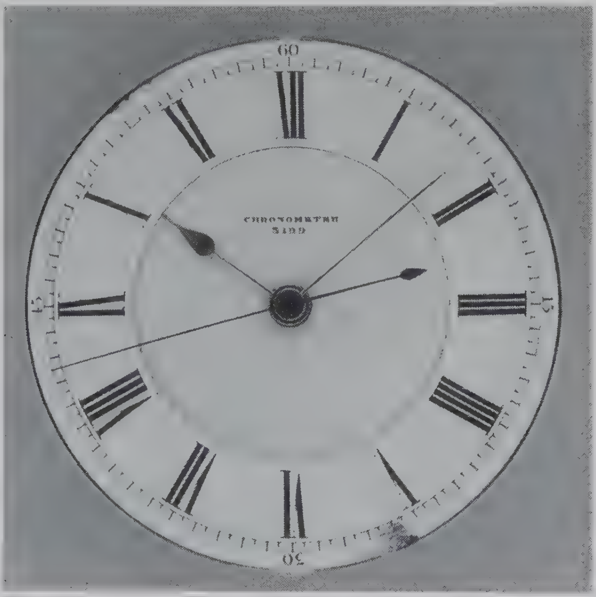
f

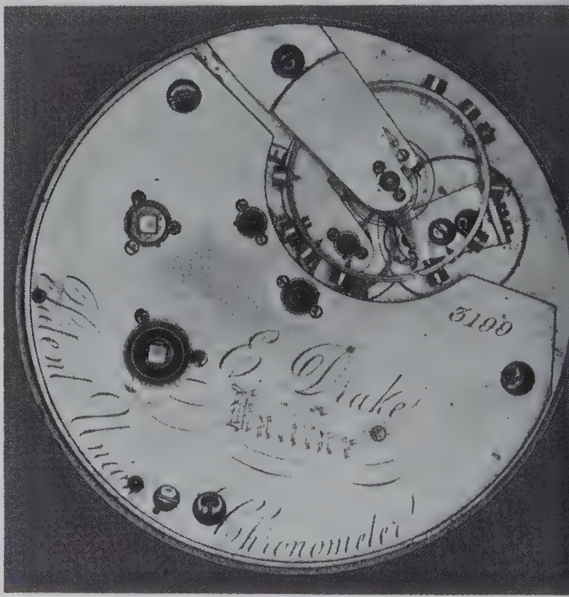
Plate 116

a. Cat. no. 158.
b. Cat. no. 158.
c. Cat. no. 159.
d. Cat. no. 159.
e. Cat. no. 159.


a


b


60
CHRONOMETER
3199
15
45
30
c


3199
E. Drake
Patent Union
Chronometer
d

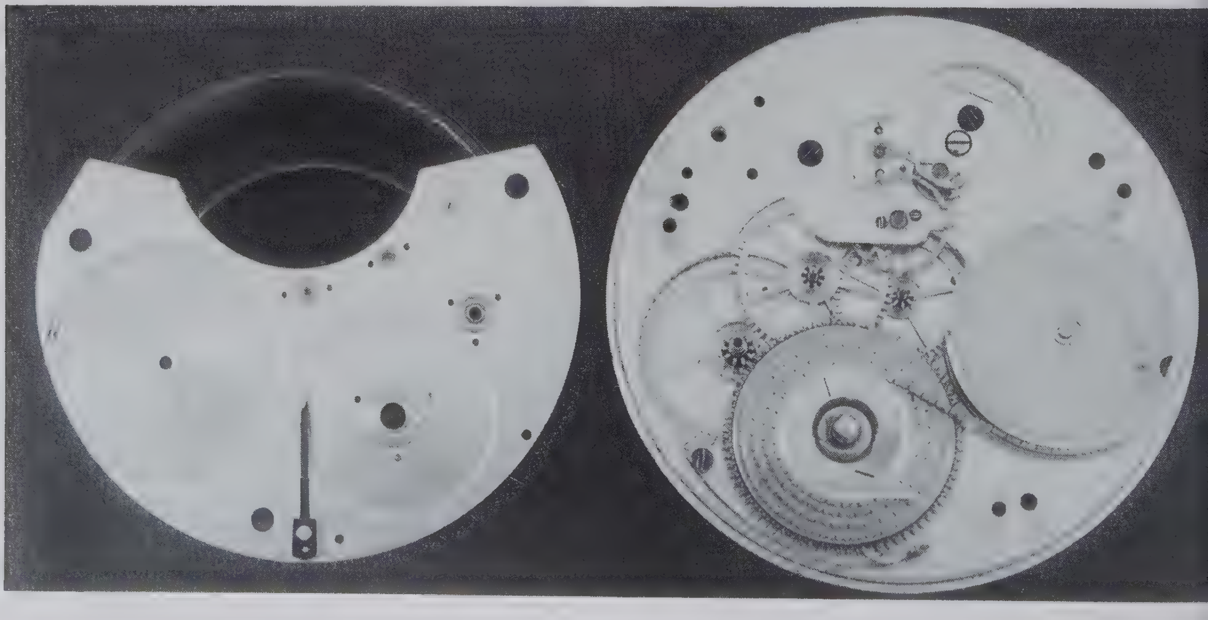
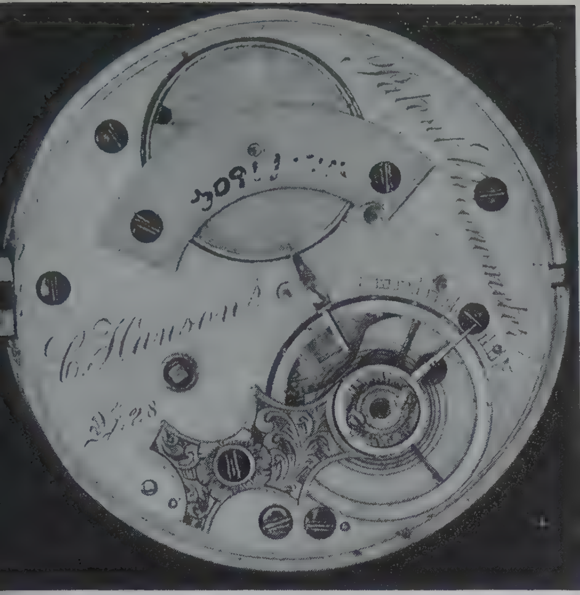
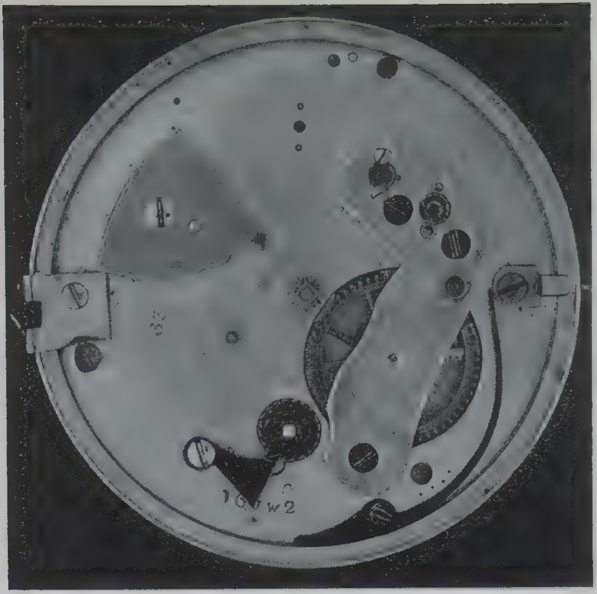

e

Plate 117

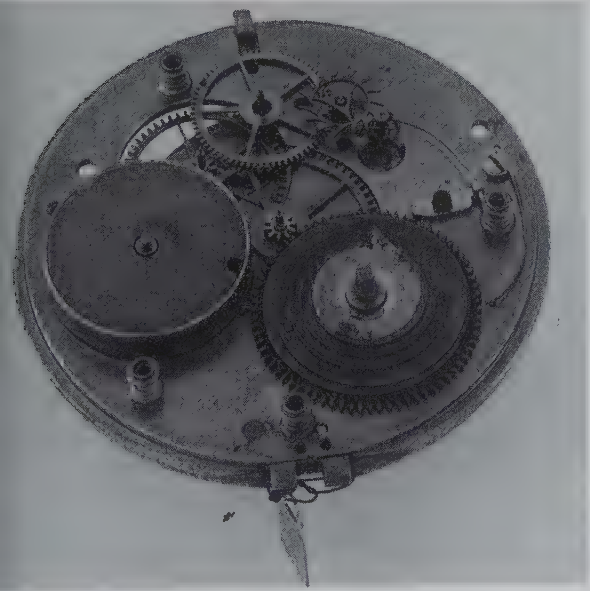
a. Cat. no. 160.
b. Cat. no. 160.
c. Cat. no. 160.
d. Cat. no. 160.
e. Cat. no. 161.
f. Cat. no. 161.



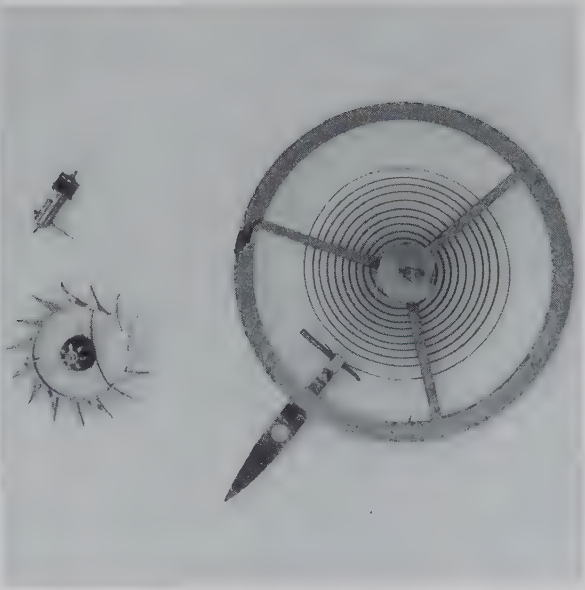
a



b



c



d

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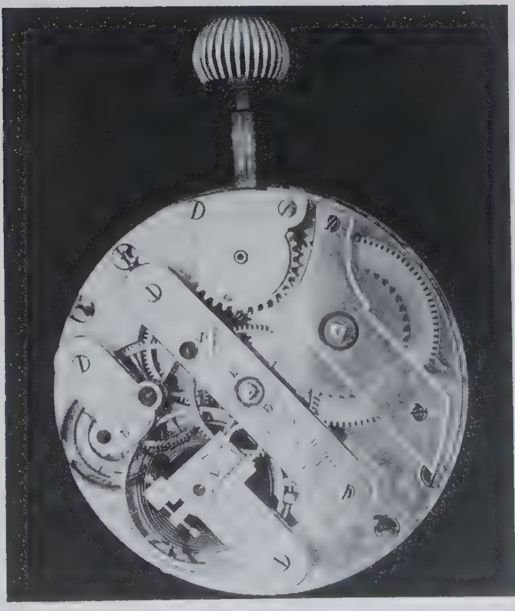
11

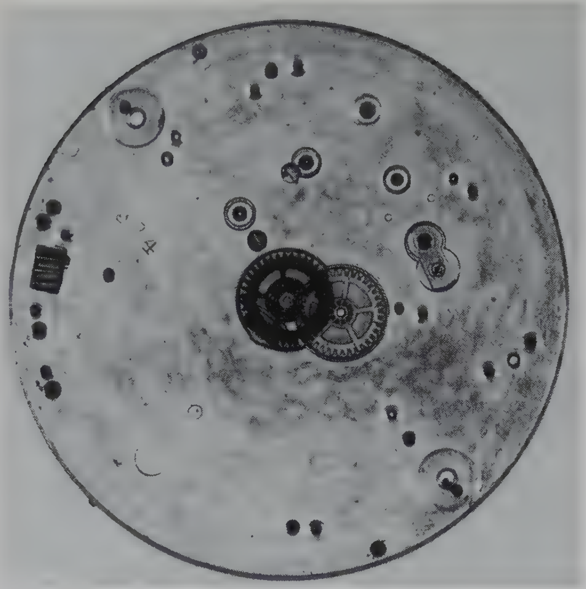
e



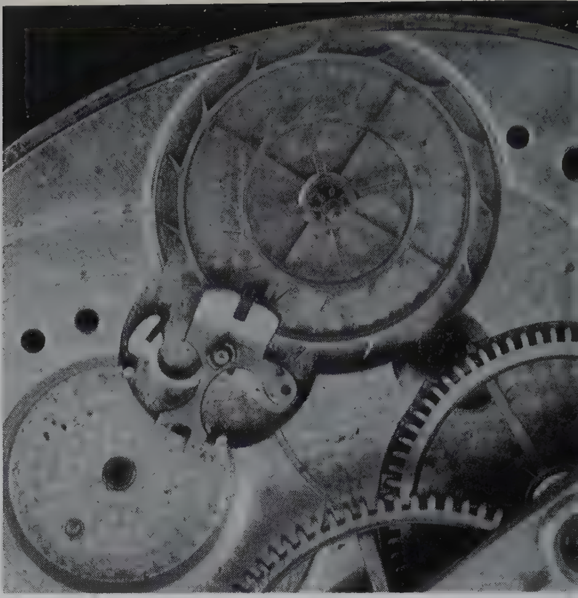
f

Plate 118

a. Cat. no. 161.
b. Cat. no. 161.
c. Cat. no. 161.
d. Cat. no. 161.



a



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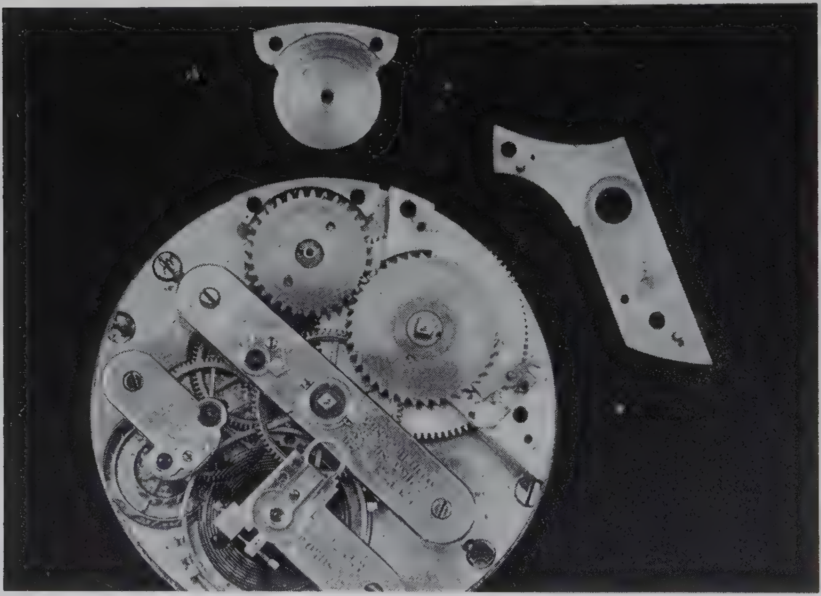
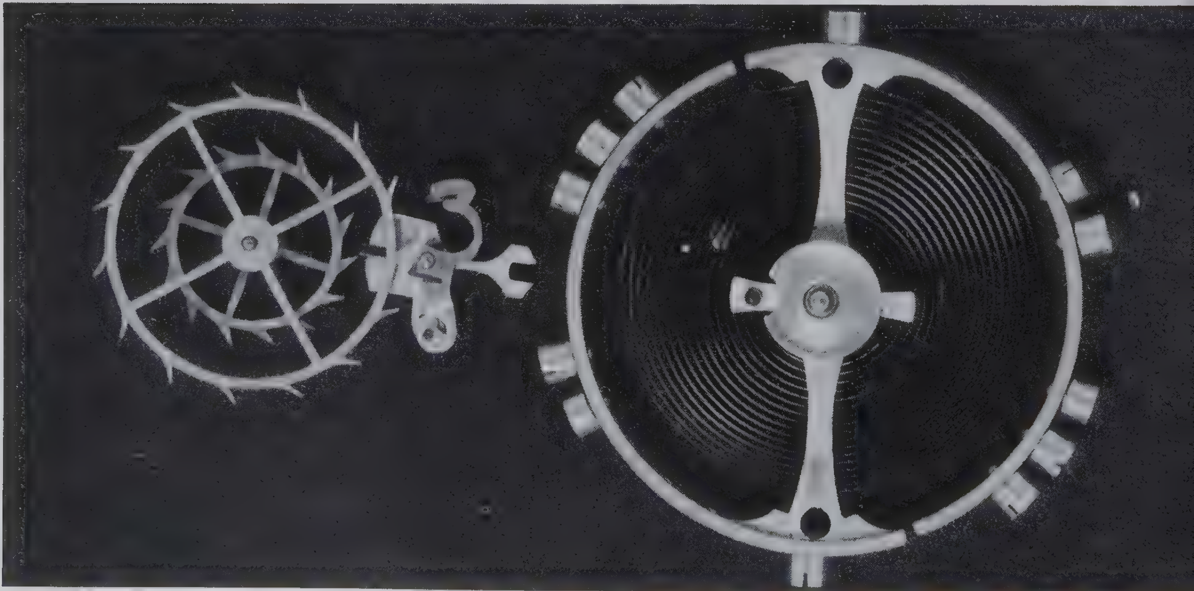


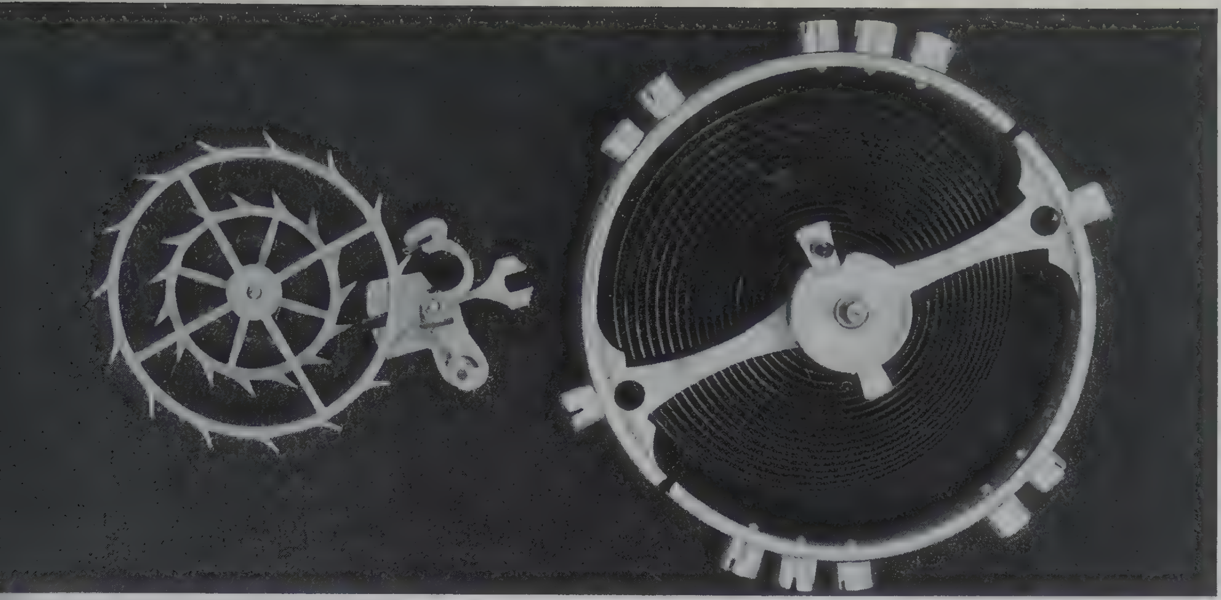
c

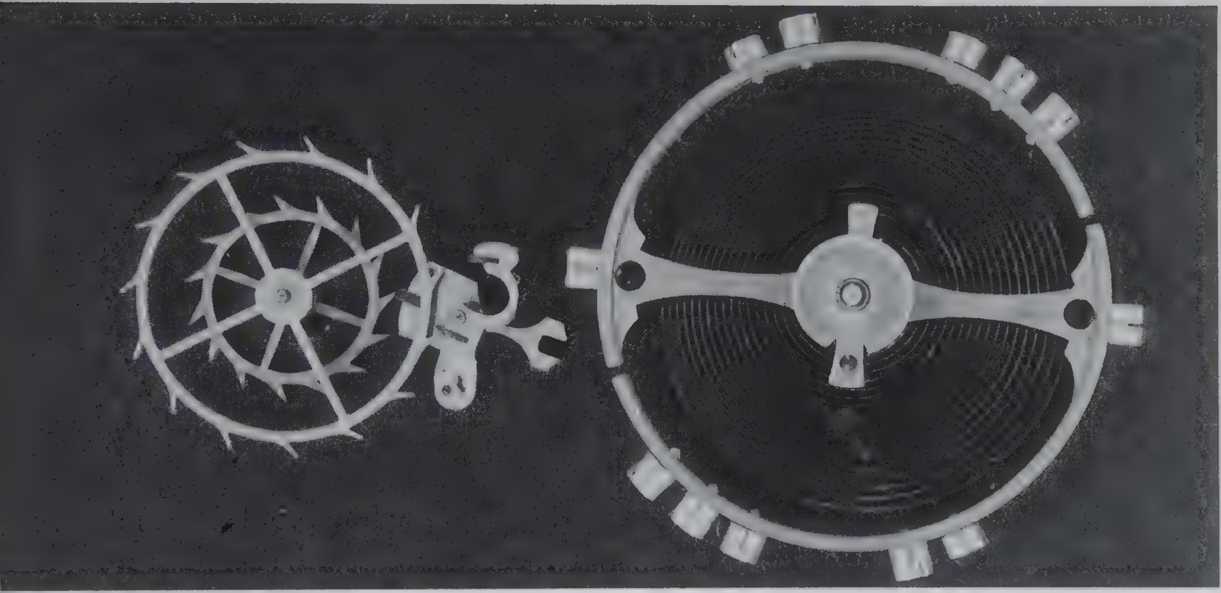


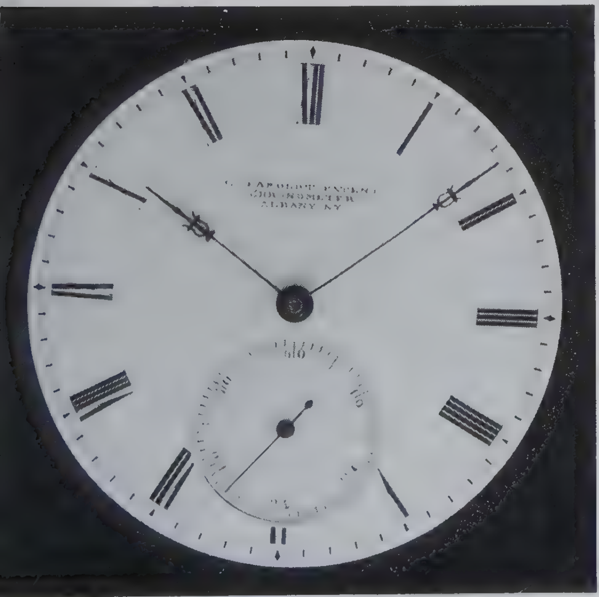
d

Plate 119

a. Cat. no. 161.
b. Cat. no. 161.
c. Cat. no. 162.
d. Cat. no. 162.


a


b


CHRONOMETER
ALBANY NY
c

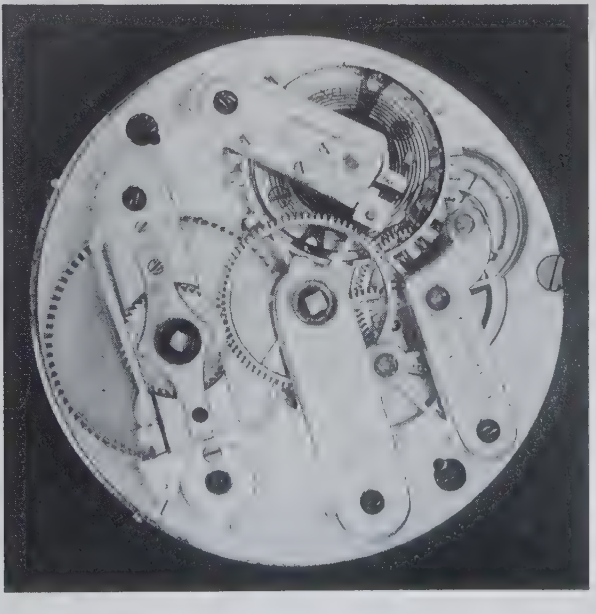
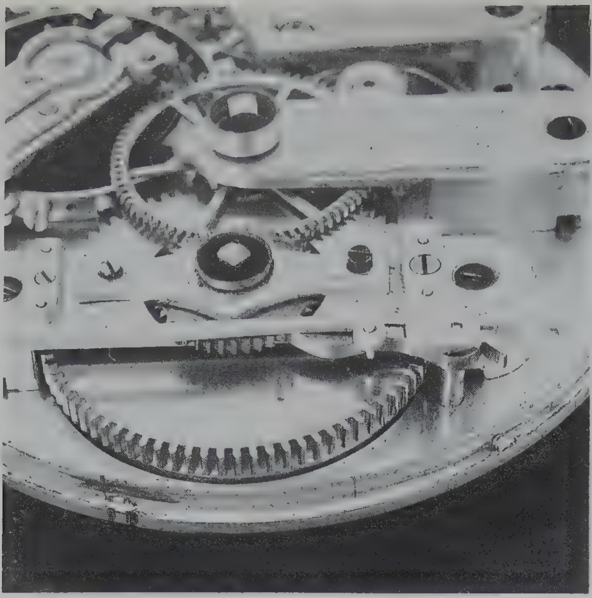
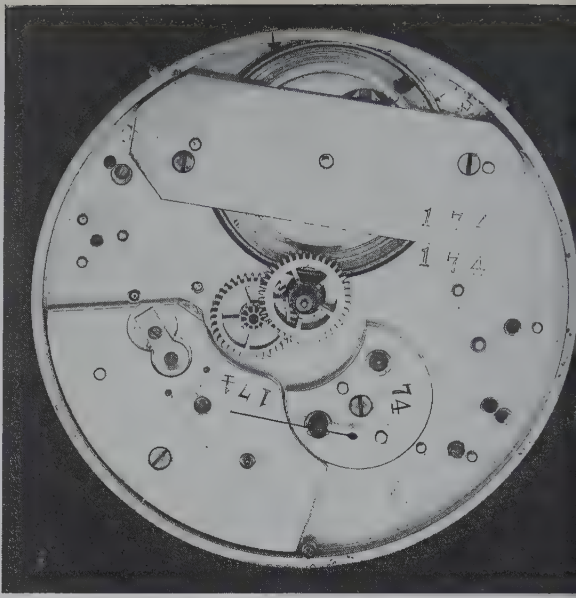
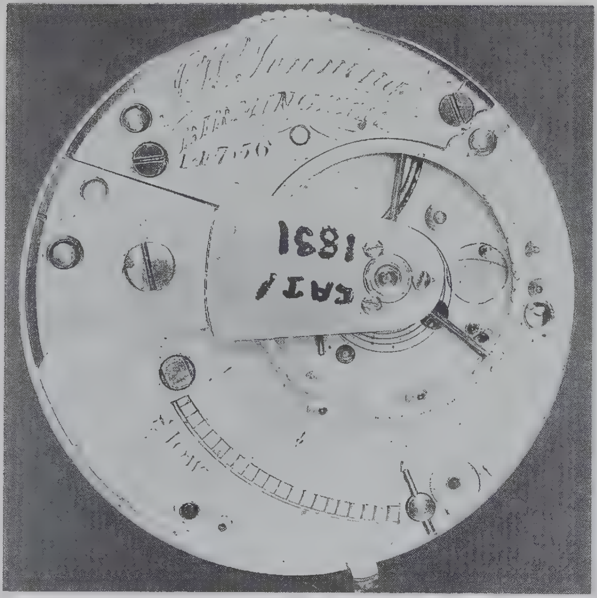

d

Plate 120

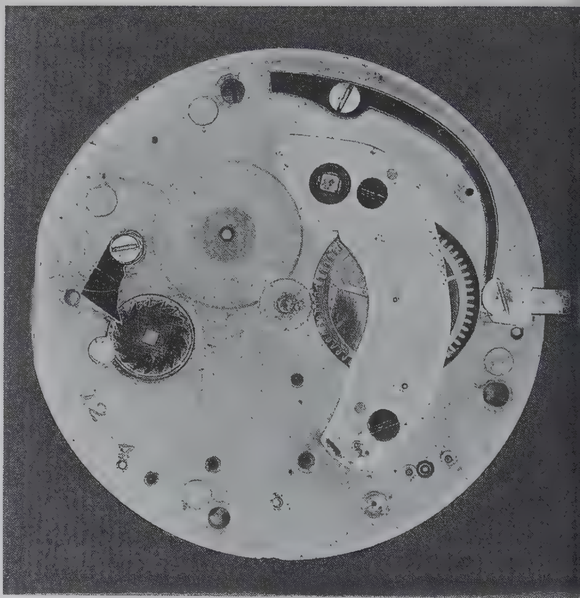
a. Cat. no. 162.
b. Cat. no. 162.
c. Cat. no. 163.
d. Cat. no. 163.
e. Cat. no. 163.
f. Cat. no. 164.
This chronometer has no dial.

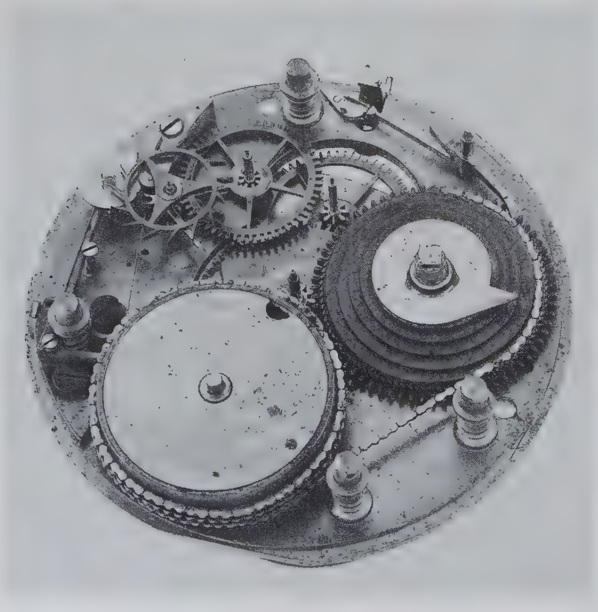

a


174
174
174
74
b



c


d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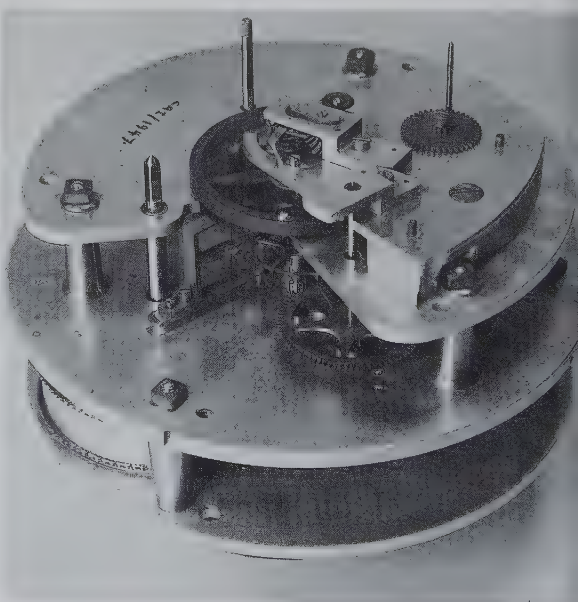
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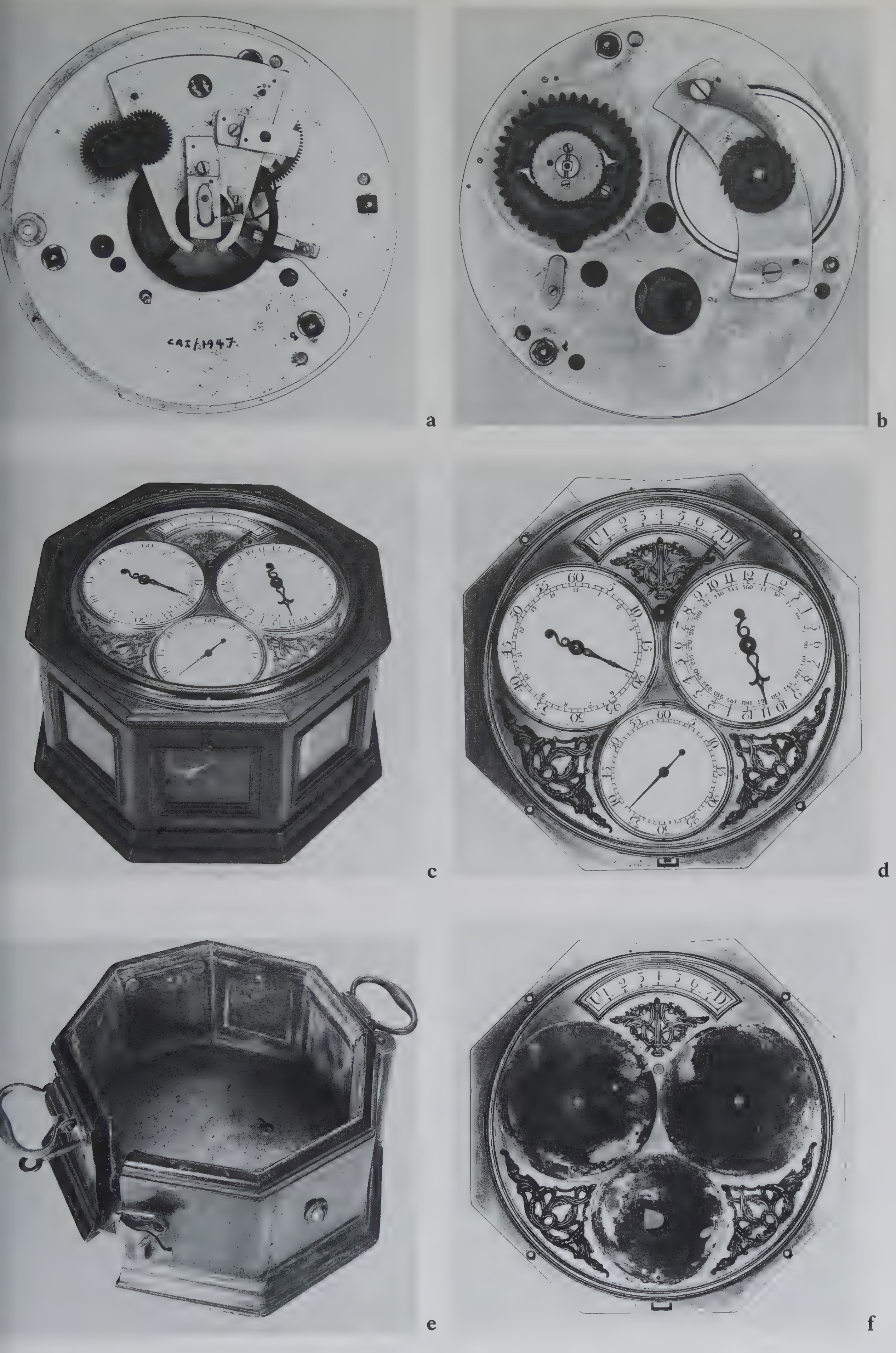
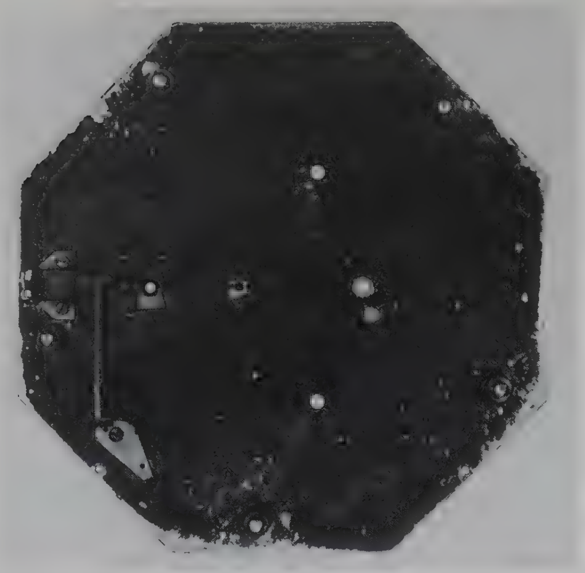

CAI/1947
a
b
c
d
e
f

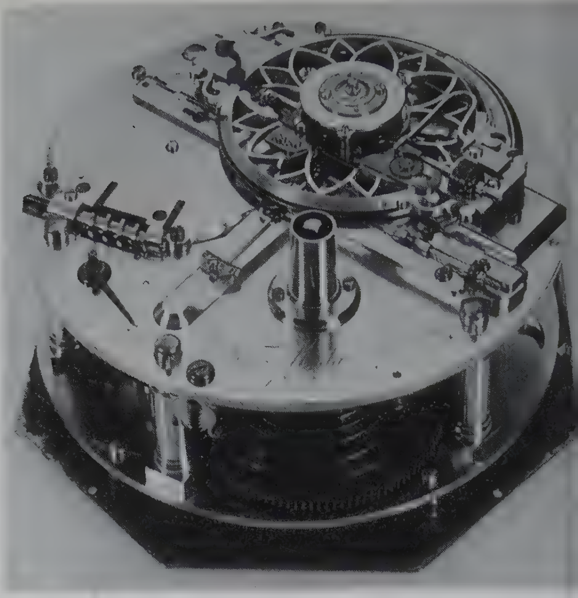
Plate 121

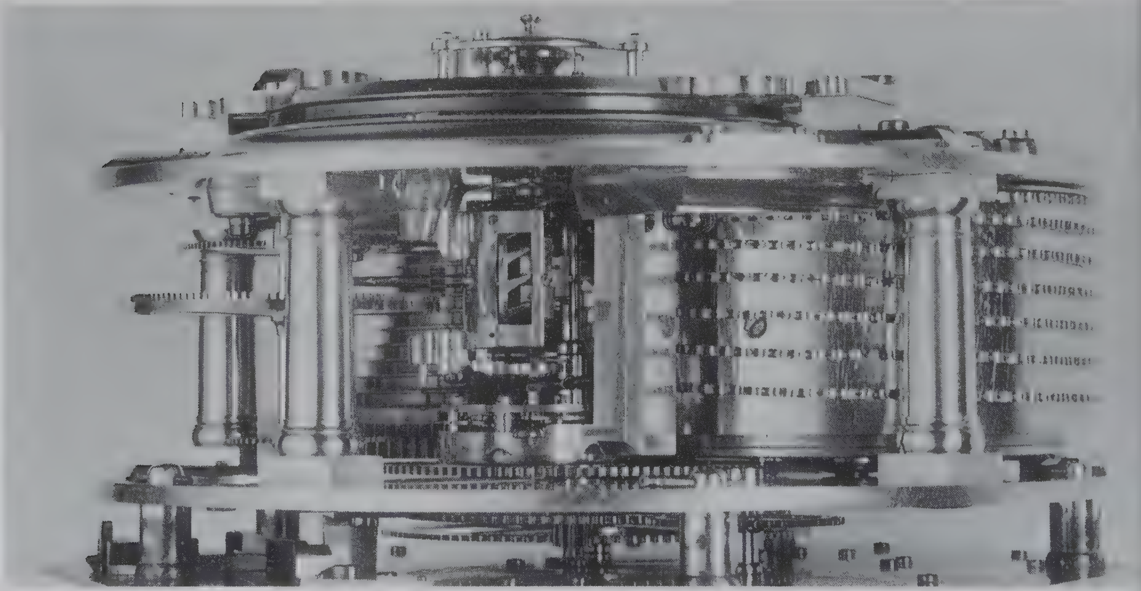
a. Cat. no. 164.
b. Cat. no. 164.
c. Cat. no. 165.
d. Cat. no. 165.
e. Cat. no. 165, the outer case with its hinged side.
f. Cat. no. 165.

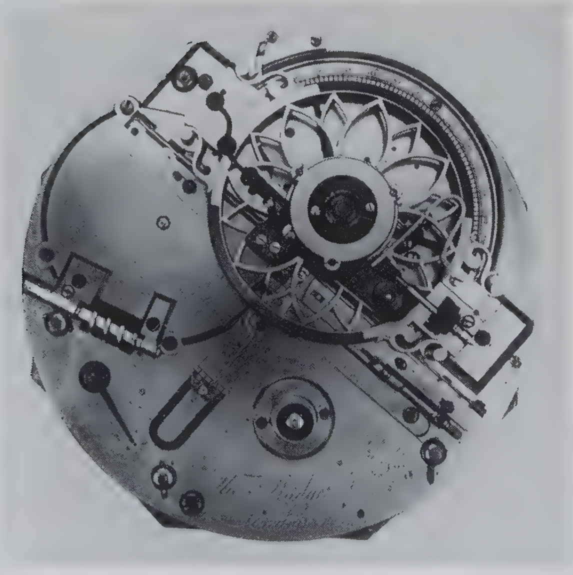
Plate 122

a. Cat. no. 165, back of dial plate.
b. Cat. no. 165.
c. Cat. no. 165.
d. Cat. no. 165.
e. Cat. no. 165, under dial.


a


b


c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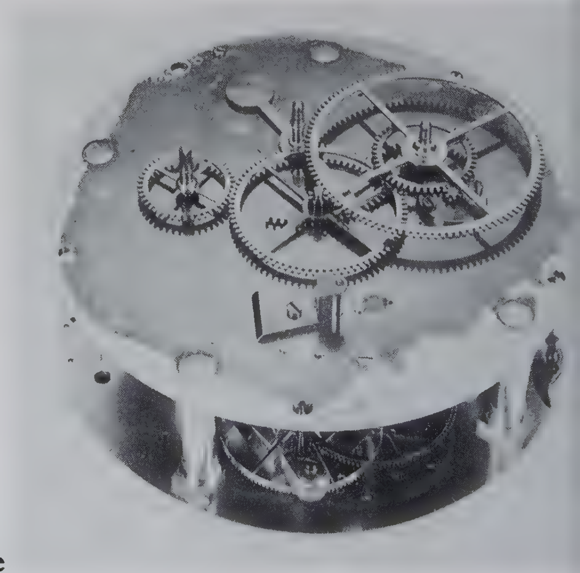

e

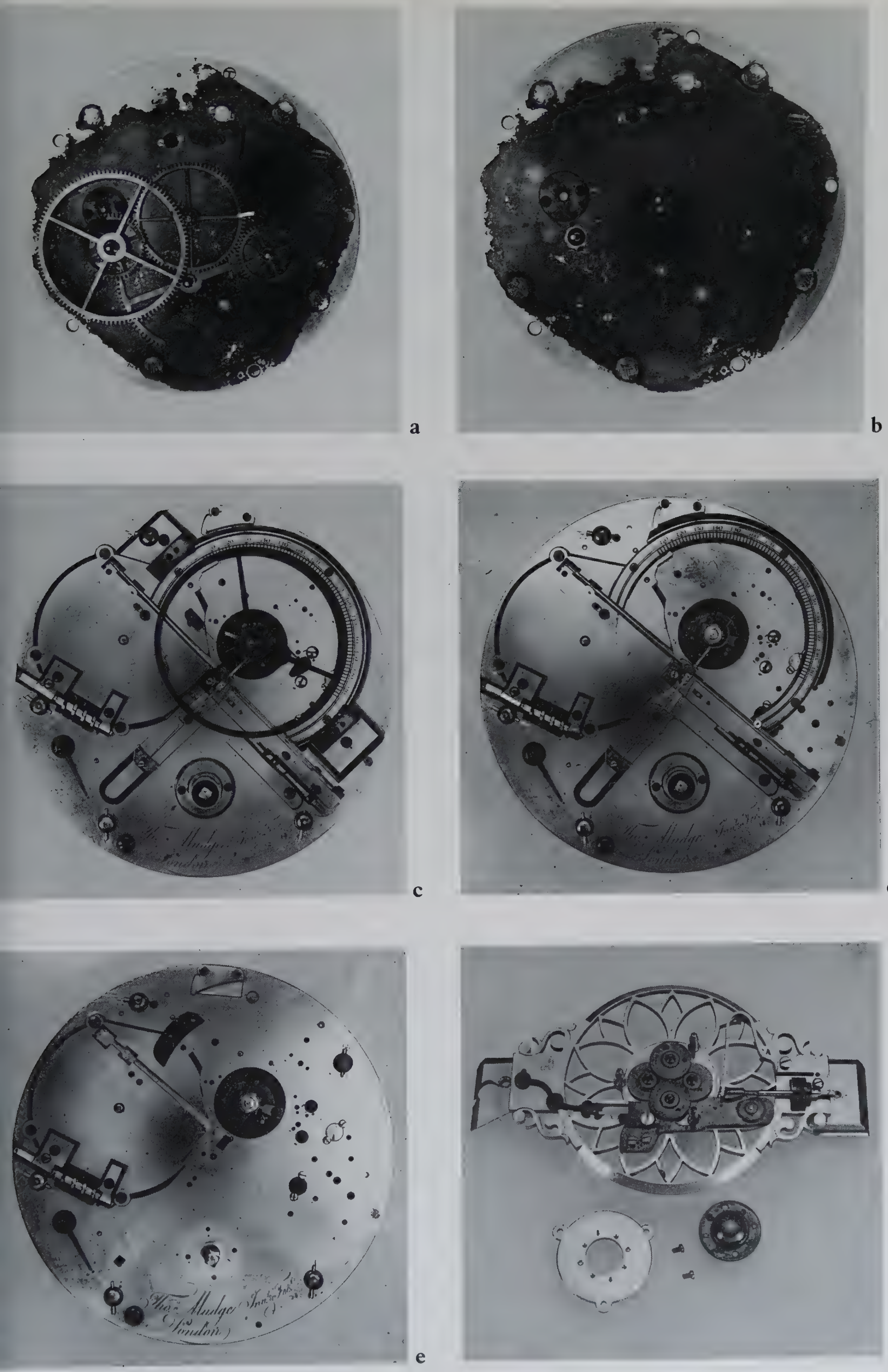


Plate 123

a. Cat. no. 165, under dial, segment gear visible.
b. Cat. no. 165, as *a* but with gearing removed.
c. Cat. no. 165, backplate and balance bridge removed.
d. Cat. no. 165, as *c* but with balance removed.
e. Cat. no. 165, as *d* but with temperature compensation removed.
f. Cat. no. 165, balance bridge with friction rollers in place, retaining plate removed.

Plate 124

a. Cat. no. 165, front plate removed, pieces sitting on backplate.
b. Cat. no. 165, backplate removed, pieces sitting on front plate.
c. Cat. no. 165, temperature compensation device.
d. Cat. no. 165, fine adjustment for temperature compensation. On the left is the isochronal adjustment device.

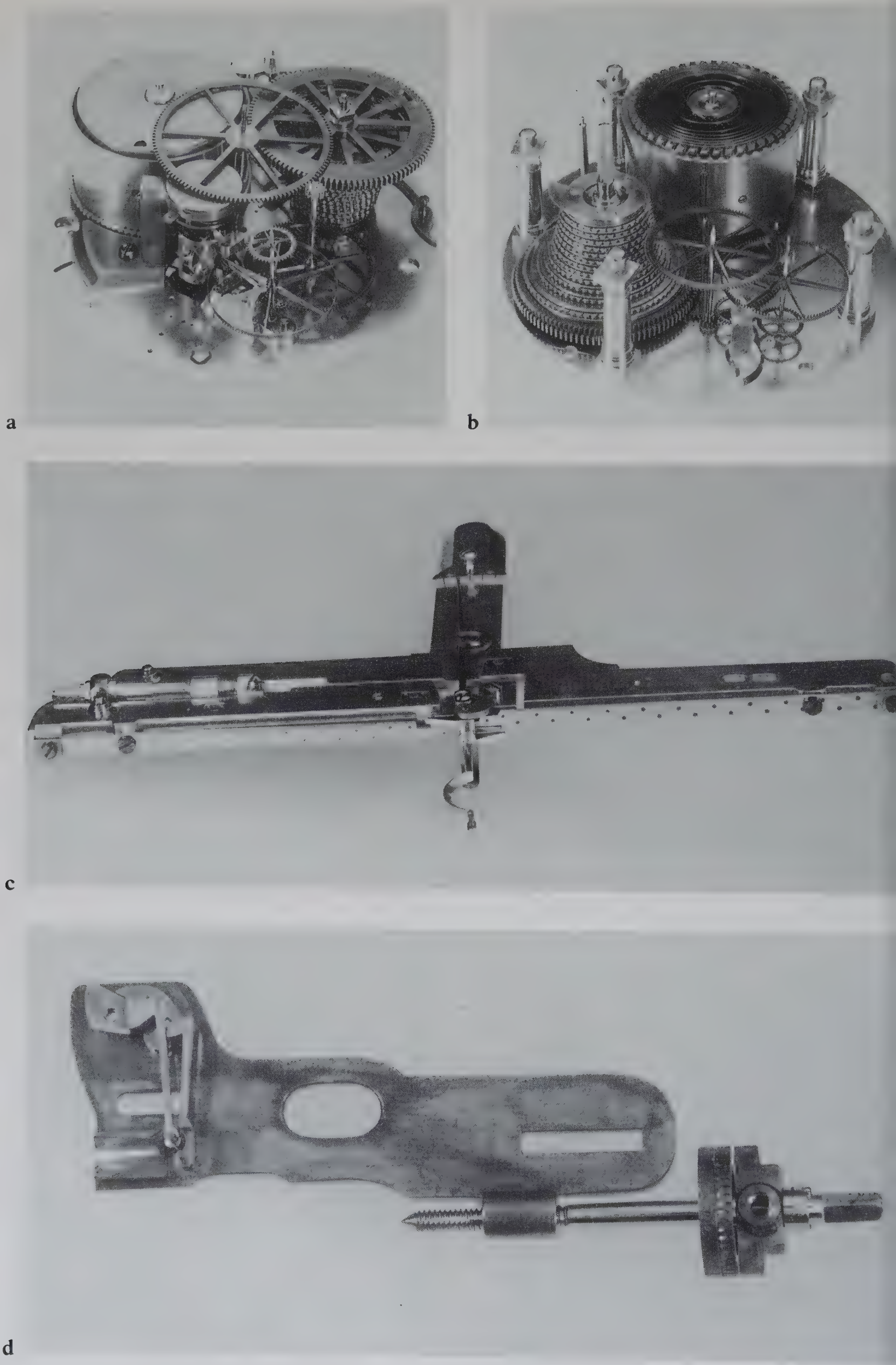
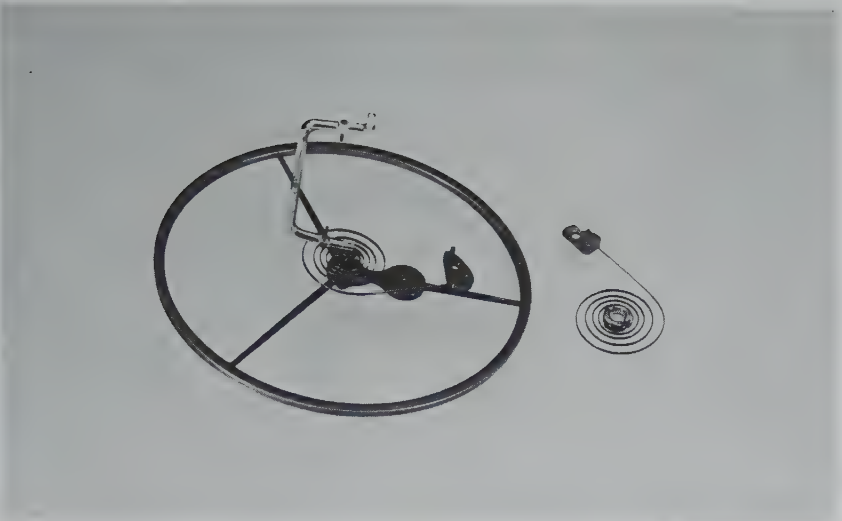
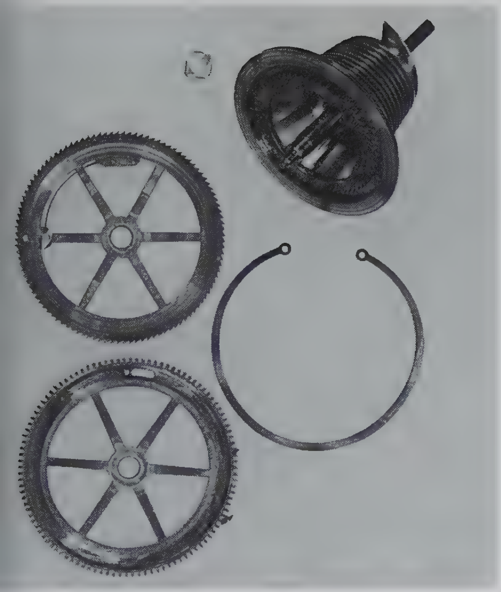
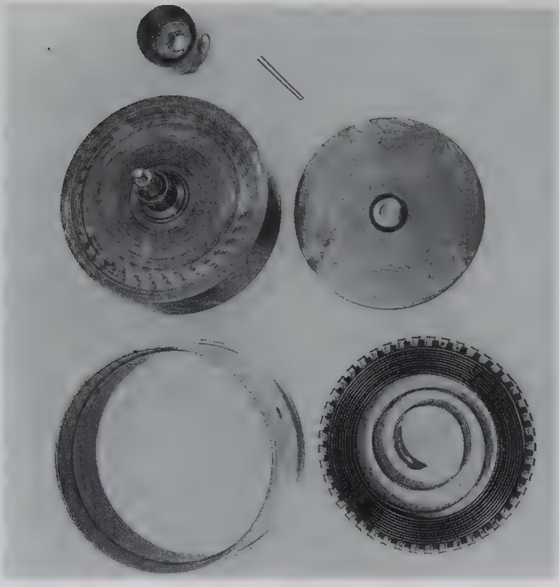


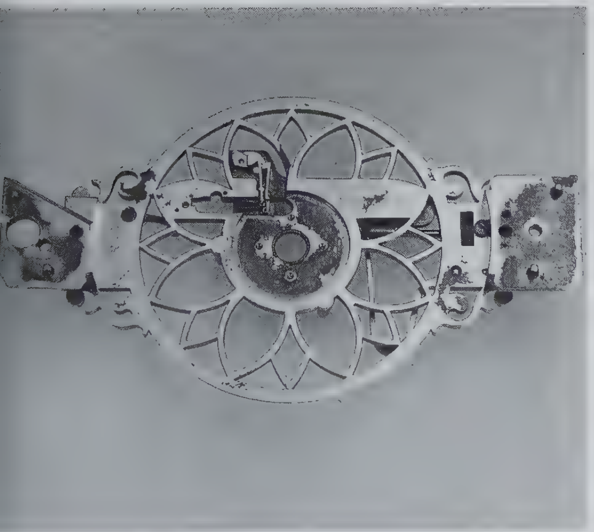
Plate 125

a. Cat. no. 165, balance with its staff and one of the two balance springs removed.
b. Cat. no. 165, fusee.
c. Cat. no. 165, barrel.
d. Cat. no. 165, underside of balance-cock revealing the isochronal adjustment device.
e. Cat. no. 165, the balance potance and escapement block, the balance in position.


a


b


c


d

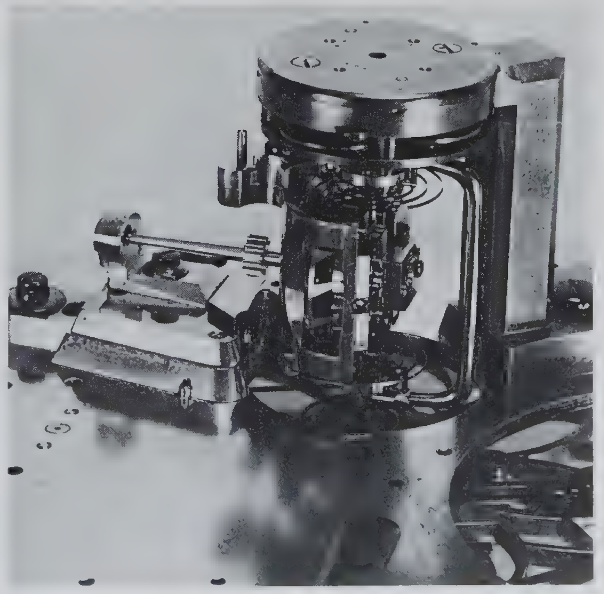

e

Plate 126

a. Cat. no. 165.
b. Cat. no. 165.
c. Cat. no. 165, escapement block.
d. Cat. no. 165.
e. Cat. no. 165.
f. Cat. no. 165, cock removed showing a remontoir spring.

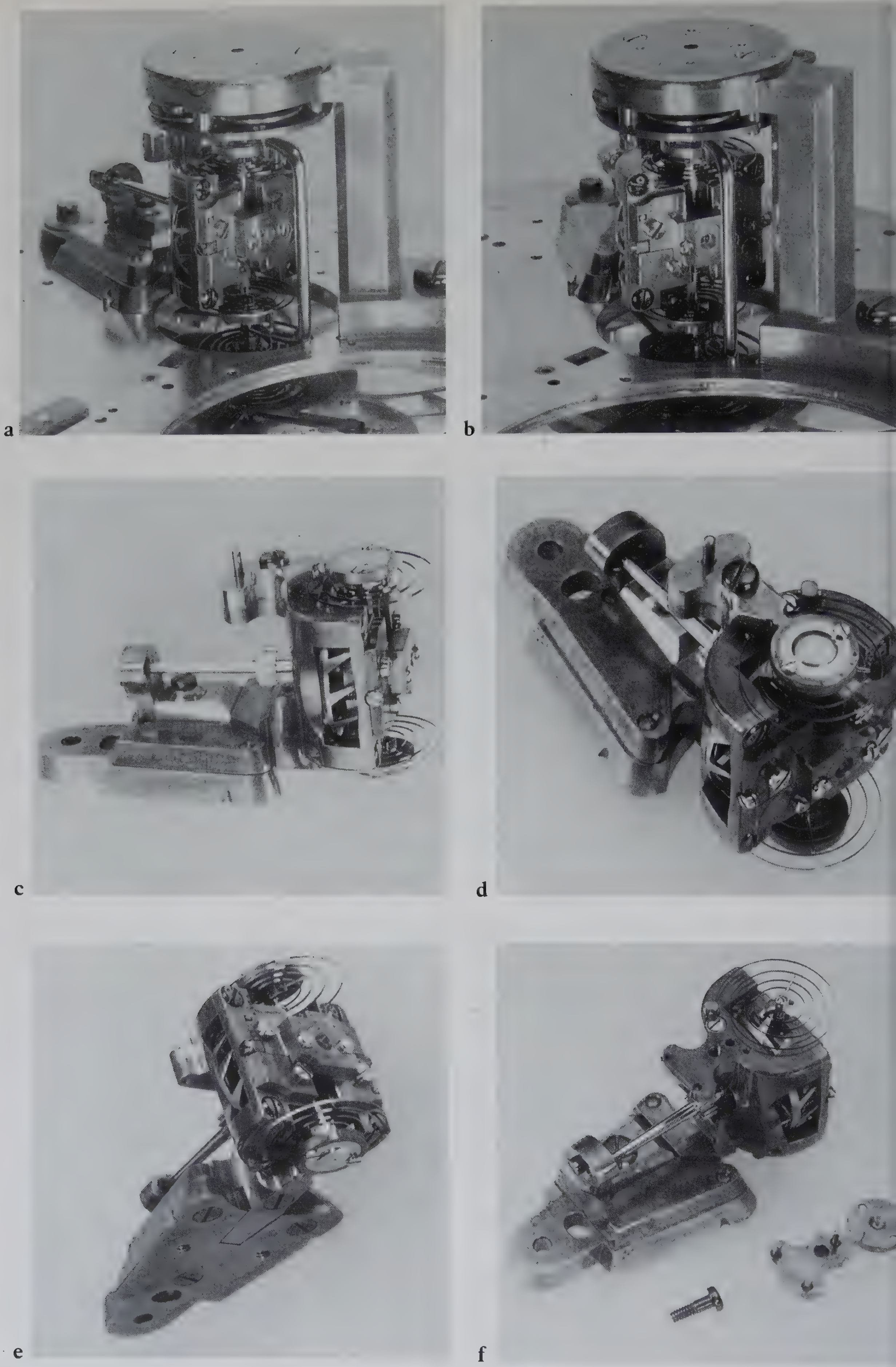
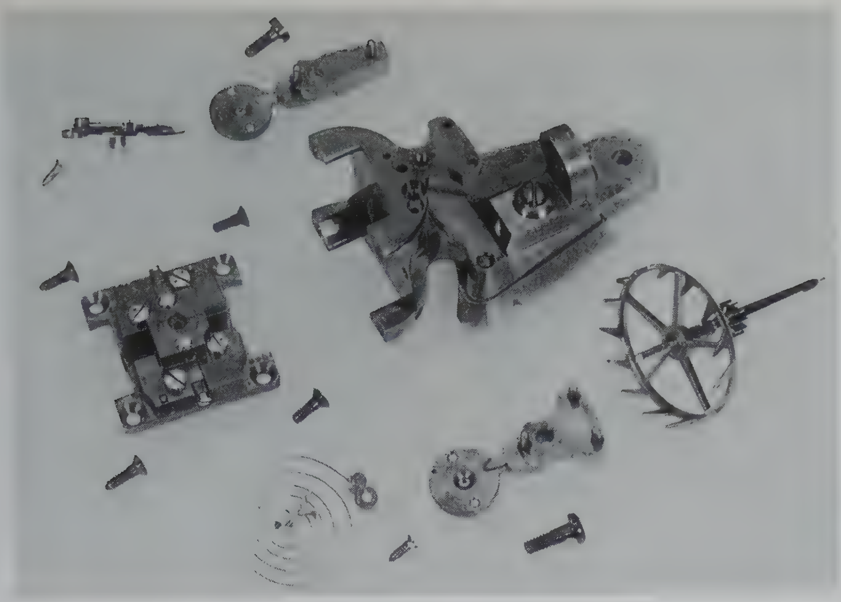
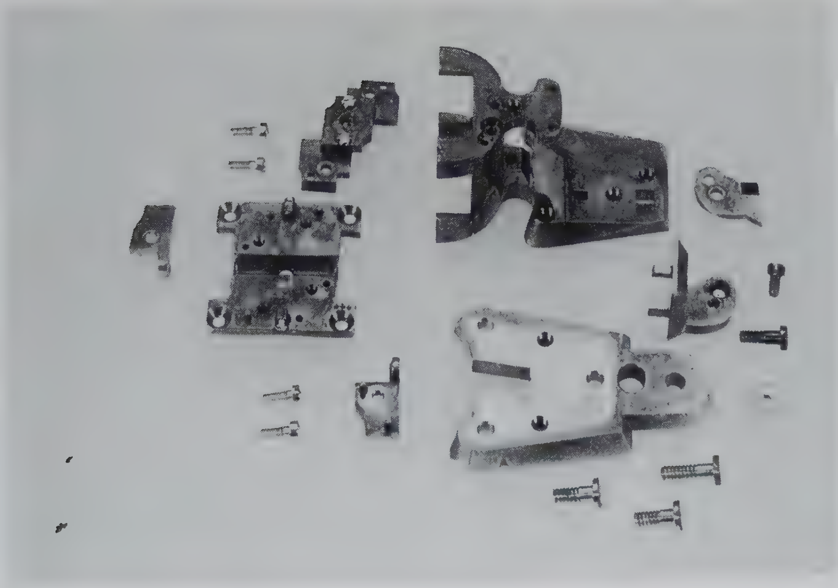


Plate 127

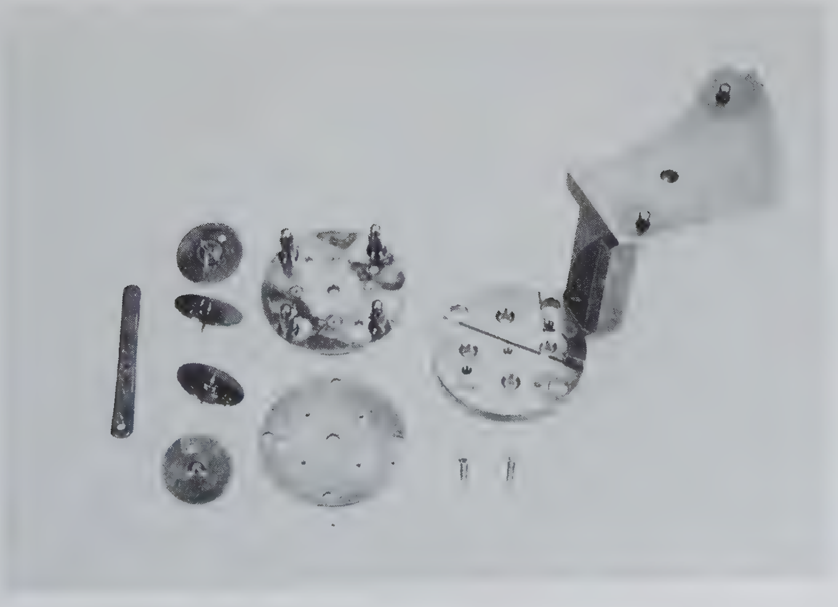
a. Cat. no. 165.
b. Cat. no. 165.
c. Cat. no. 165, potance disassembled showing friction rollers.



a



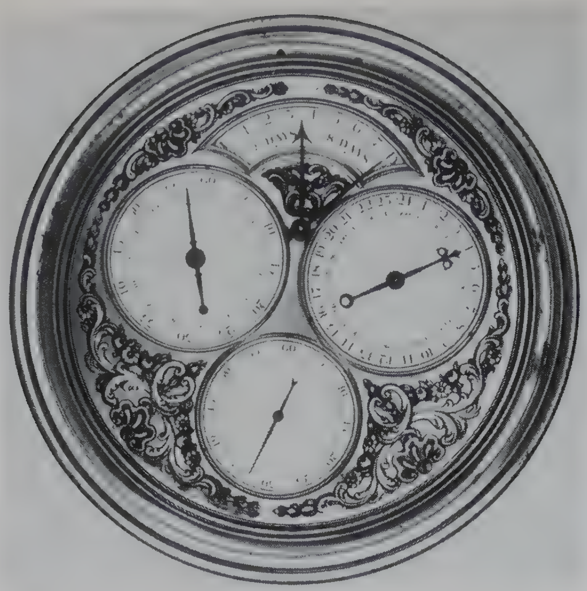
b



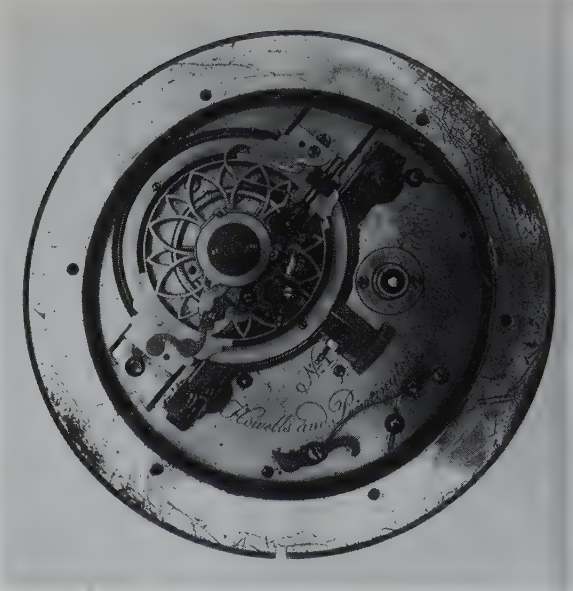
c

Plate 128

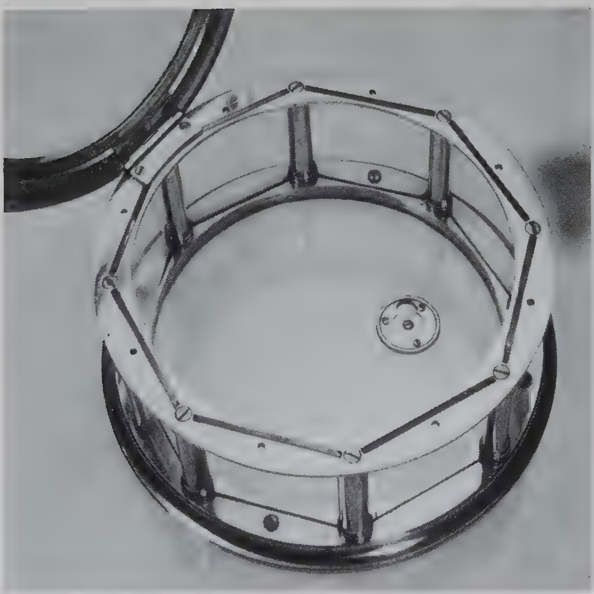
a. Cat. no. 166.
b. Cat. no. 166.
c. Cat. no. 166.
d. Cat. no. 166.
e. Cat. no. 166.



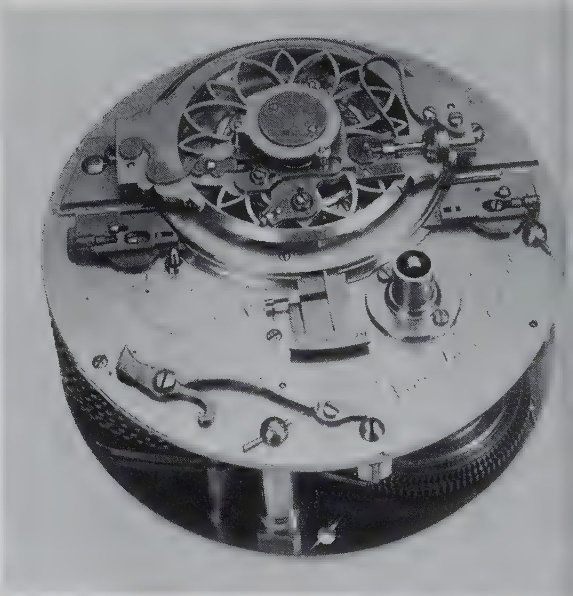
a


No.
Howells and Pennington

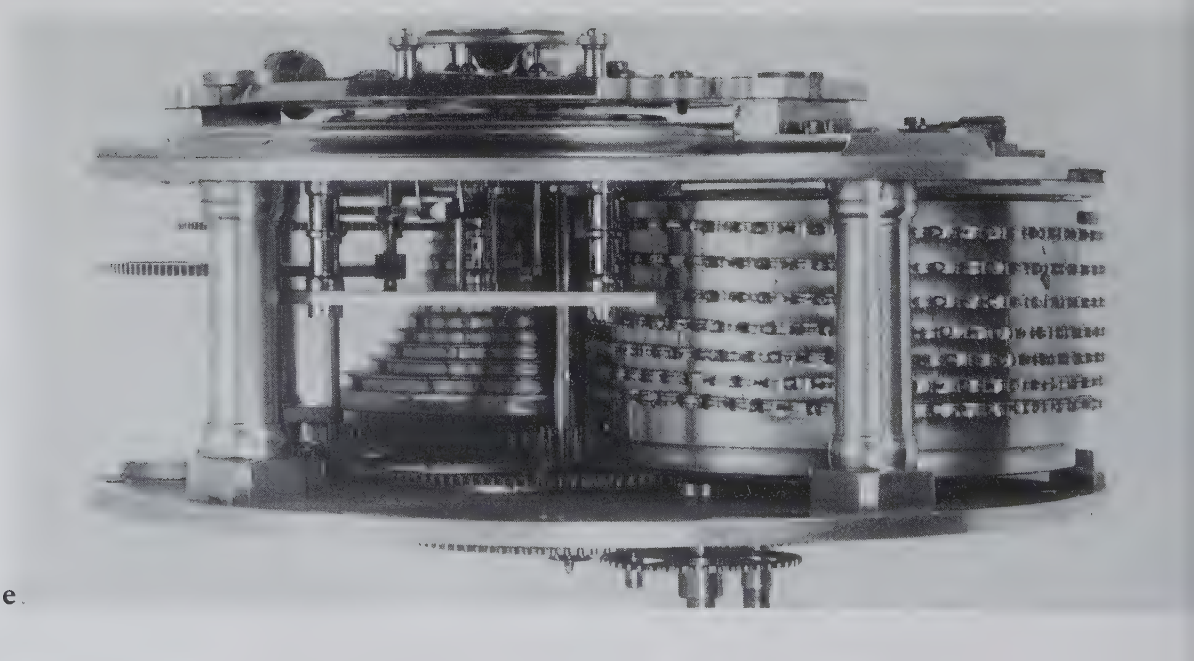
b



c



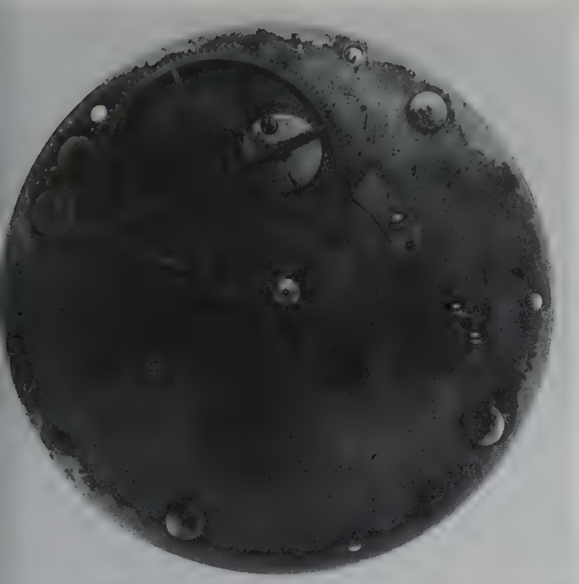
d

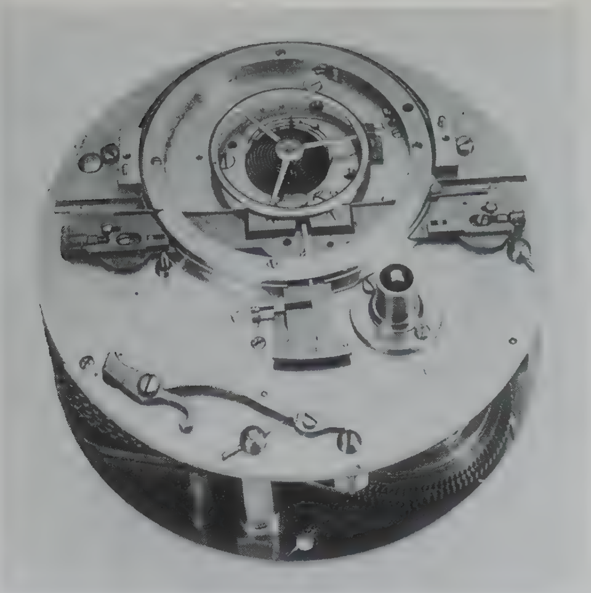


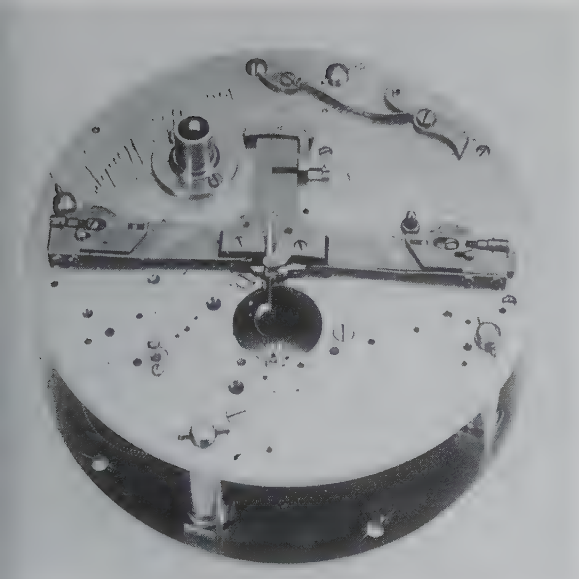
e

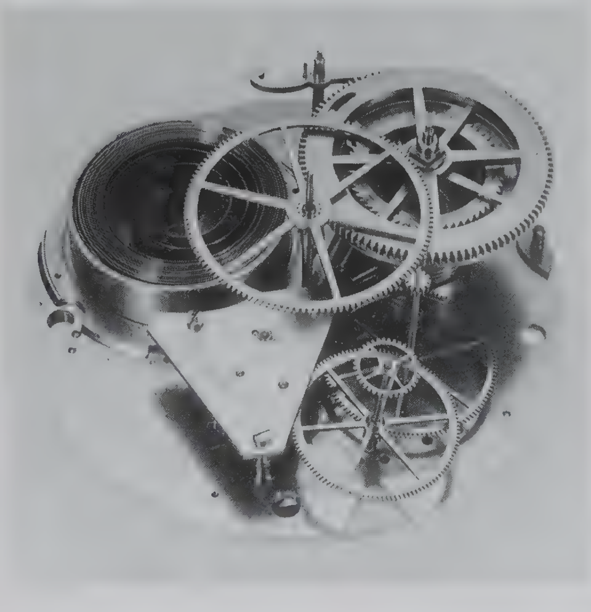
Plate 129

a. Cat. no. 166.
b. Cat. no. 166.
c. Cat. no. 166.
d. Cat. no. 166.
e. Cat. no. 166, temperature compensation device.


a


b


c


d

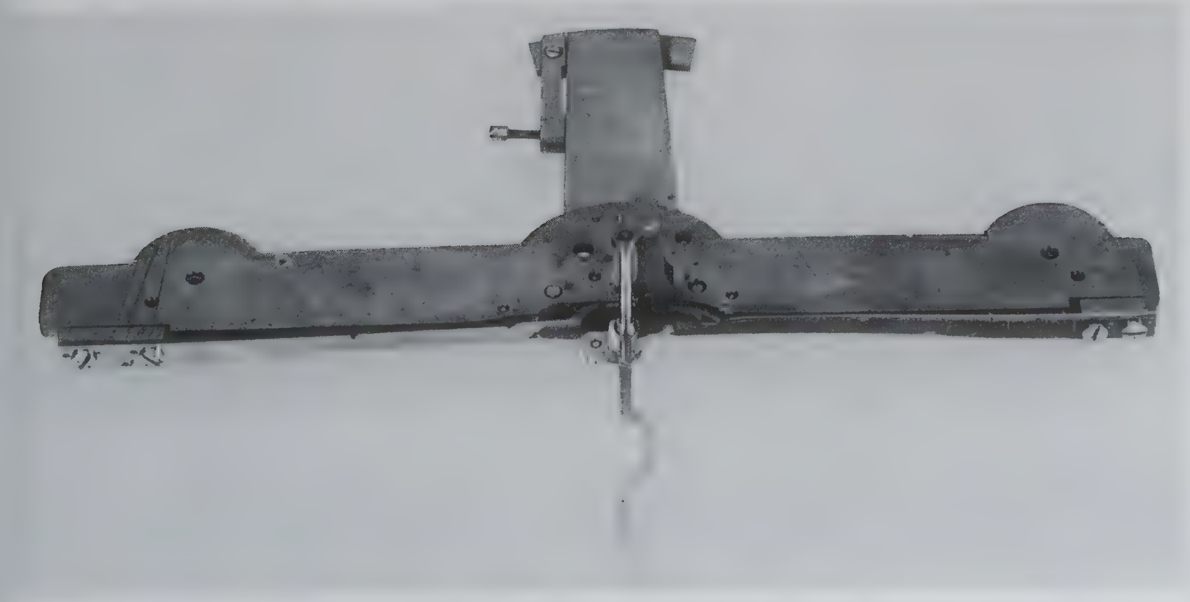
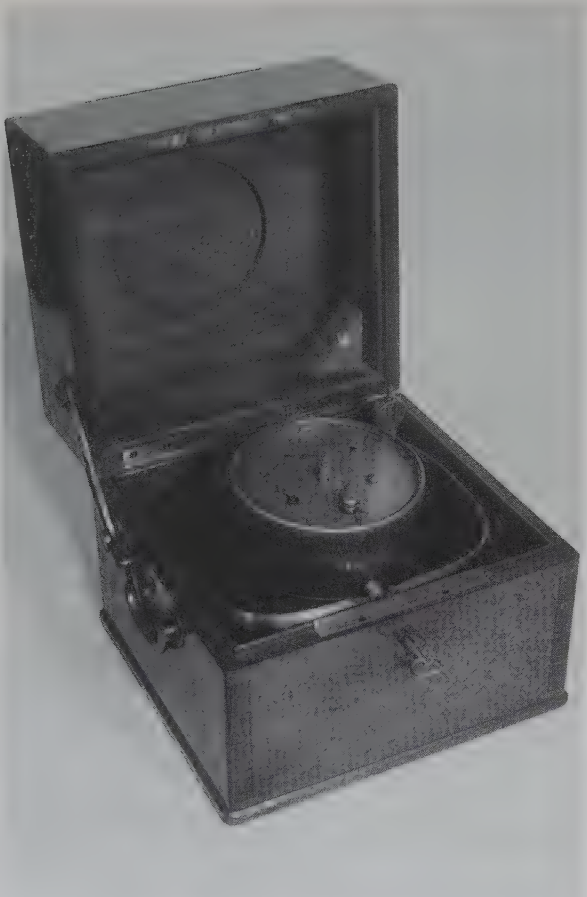
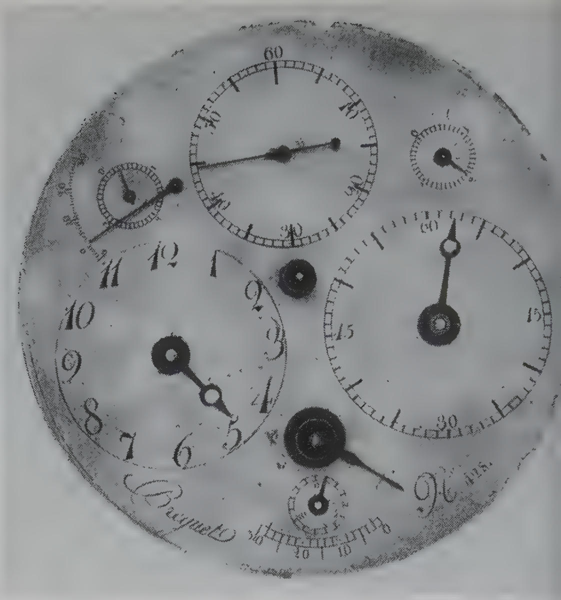

e

Plate 130

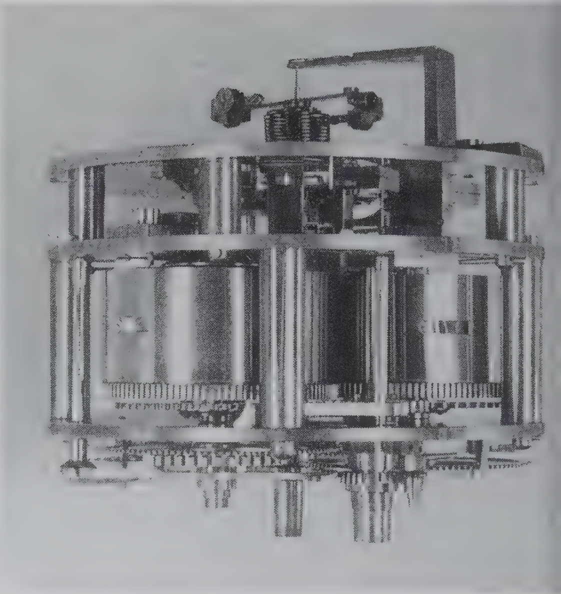
a. Cat. no. 167.
b. Cat. no. 167.
c. Cat. no. 167.
d. Cat. no. 167, under dial work.
e. Cat. no. 167.



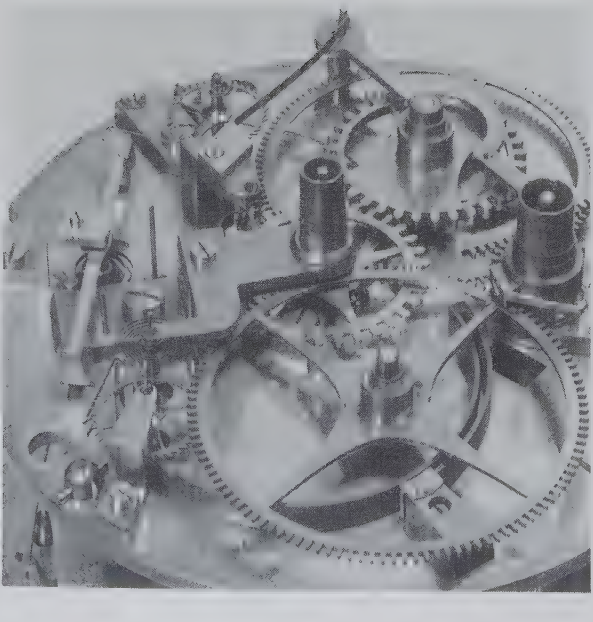
a



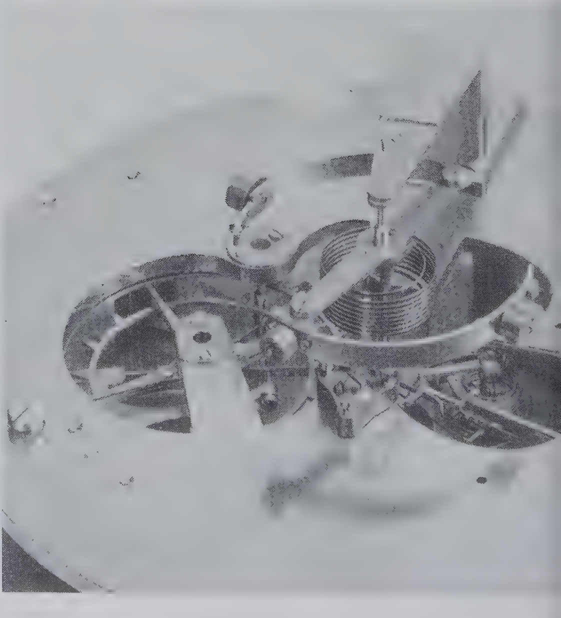
b



c



d



e

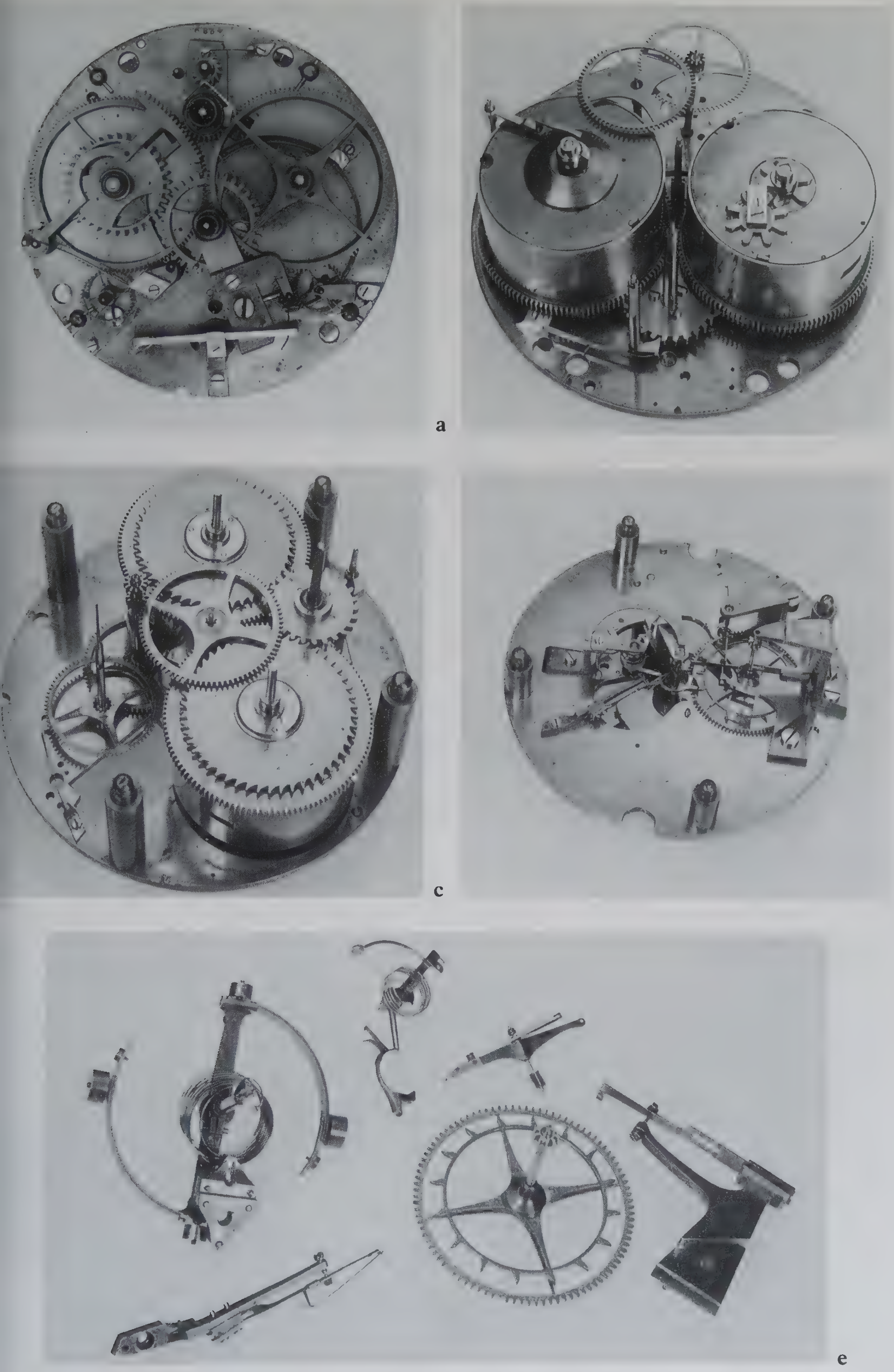


Plate 131

a. Cat. no. 167, under dial work.
b. Cat. no. 167, sub-plates and main backplates removed to show barrels.
c. Cat. no. 167, front plate removed, parts standing on the backplate.
d. Cat. no. 167, sub-plate and constant force escapement, balance still in position.
e. Cat. no. 167, constant-force escapement parts and balance.

Plate 132

a. Cat. no. 168.
b. Cat. no. 168.
c. Cat. no. 168.
d. Cat. no. 168, backplate removed.
e. Cat. no. 168, balance and escapement parts.

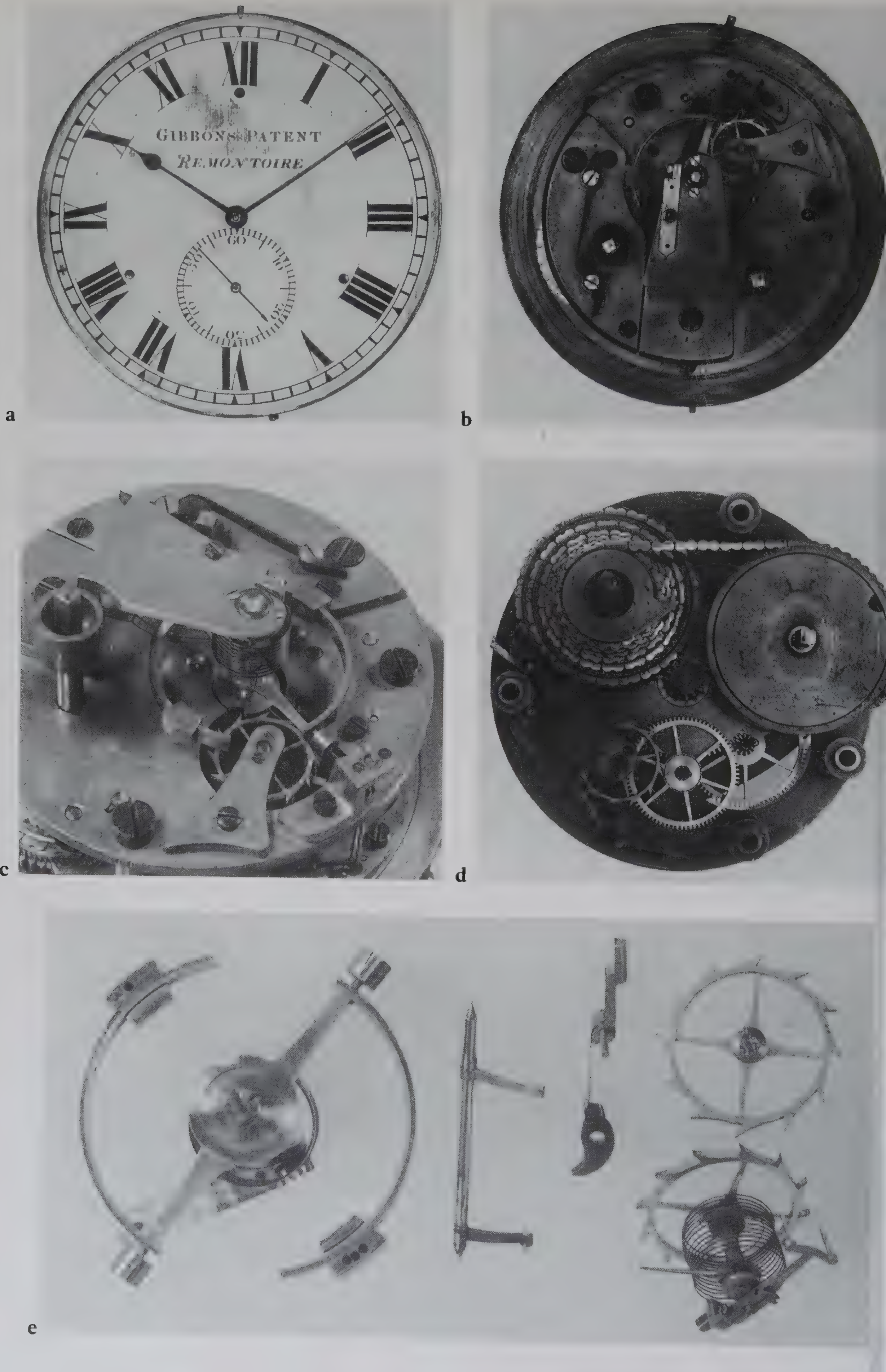
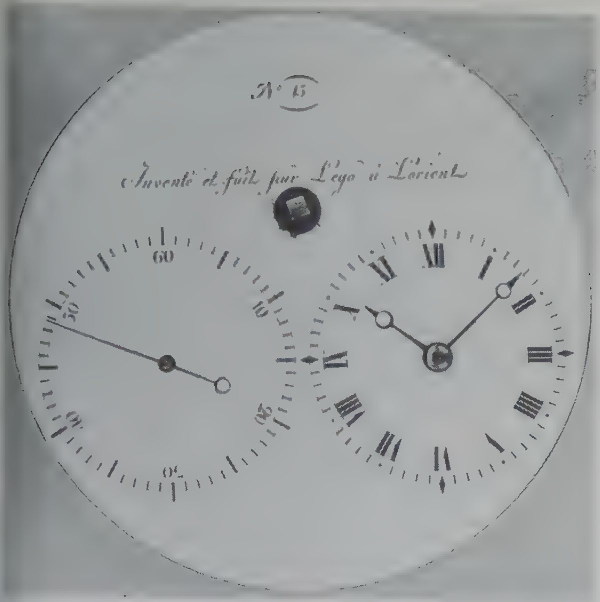
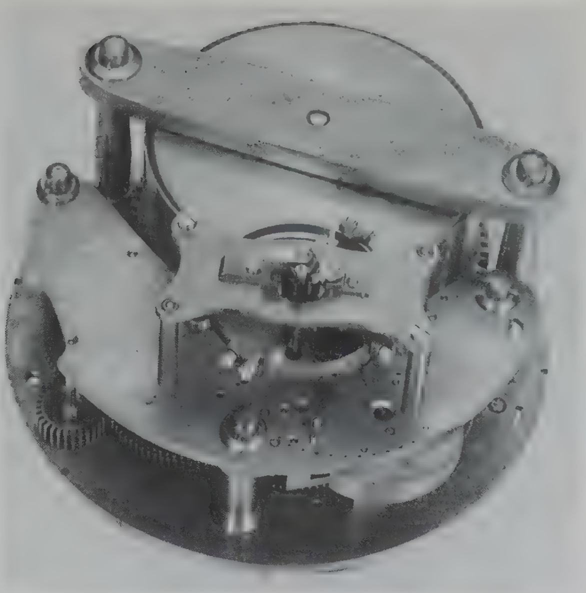

GIBBONS PATENT
REMONTOIRE
60
a
b
c
d
e

Plate 133

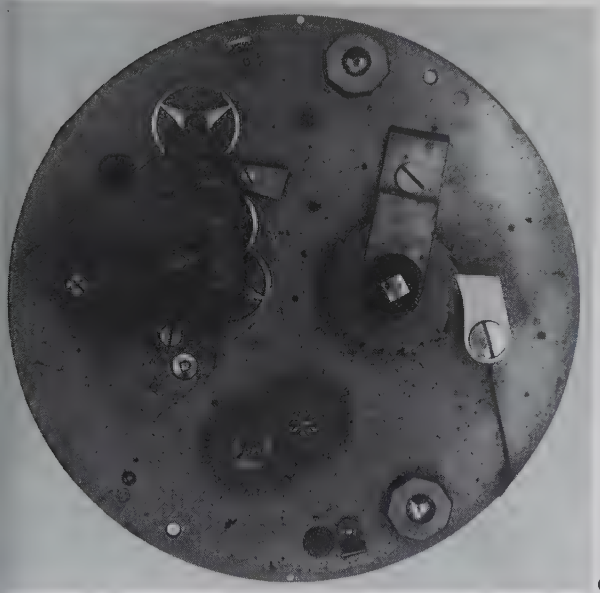
a. Cat. no. 169.
b. Cat. no. 169.
c. Cat. no. 169.
d. Cat. no. 169, friction rollers.
e. Cat. no. 169.
f. Cat. no. 169.


N° 15
Inventé et fait par L'ego à Lorient
60
10
30
50
40
20
XII
I
II
III
IV
V
VI
VII
VIII
IX
X
XI

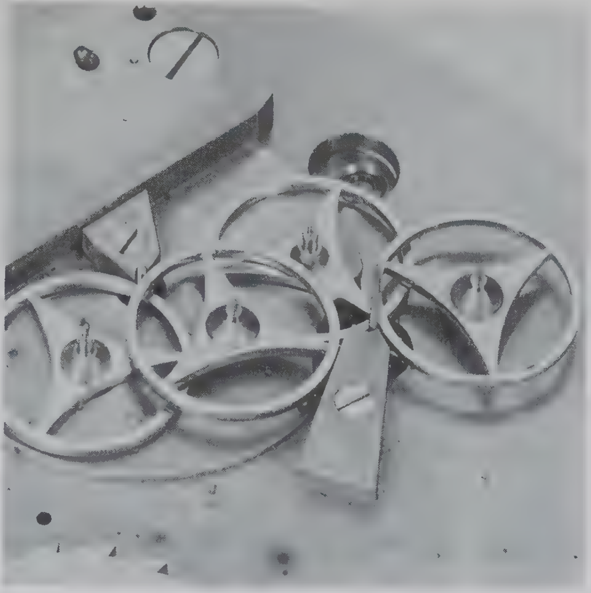
a



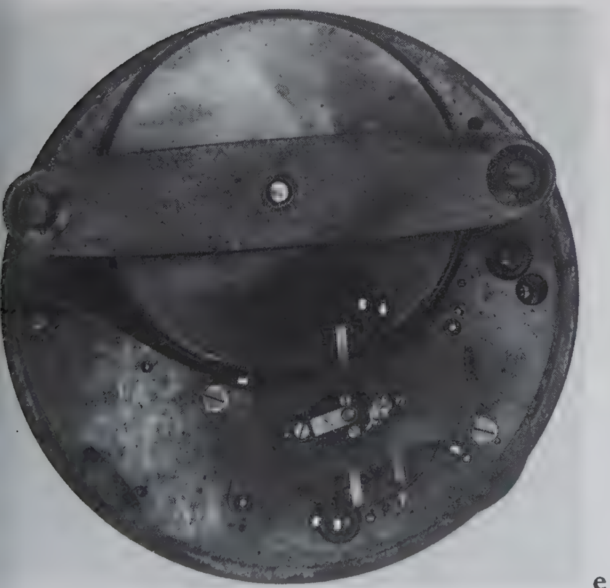
b



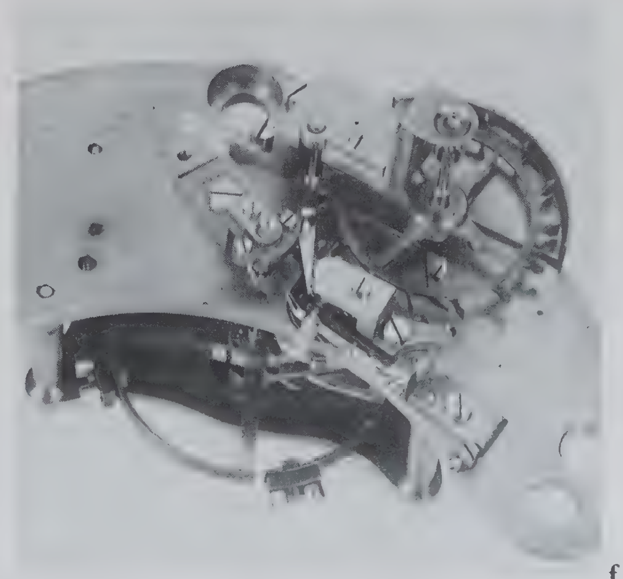
c



d



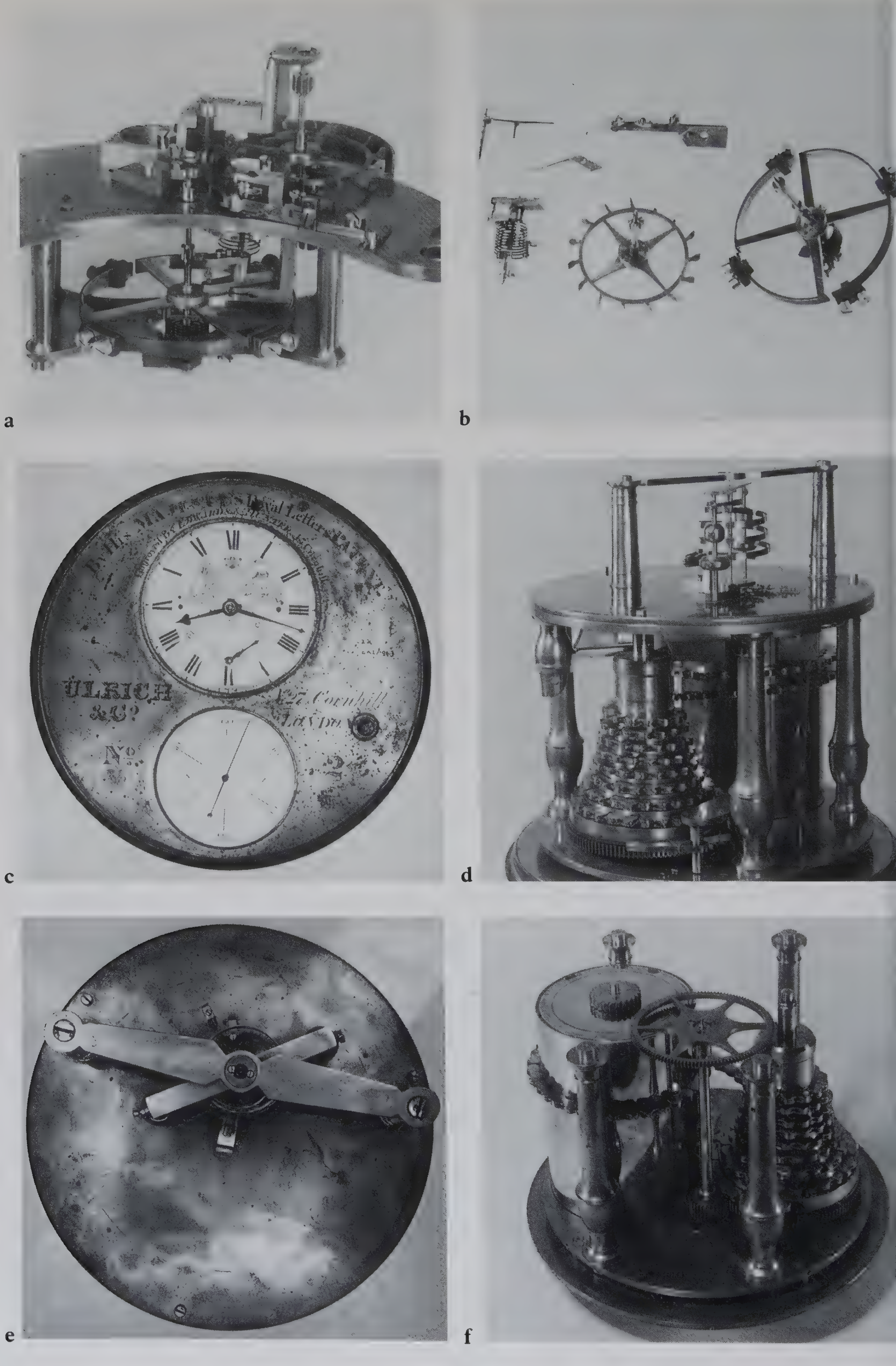
e



f

Plate 134

a. Cat. no. 169.
b. Cat. no. 169.
c. Cat. no. 170.
d. Cat. no. 170.
e. Cat. no. 170.
f. Cat. no. 170, backplate removed.


a
b
By His MAJESTY'S Royal Letters PATENT
ULRICH
&Co
27 Cornhill
London
No.
c
d
e
f

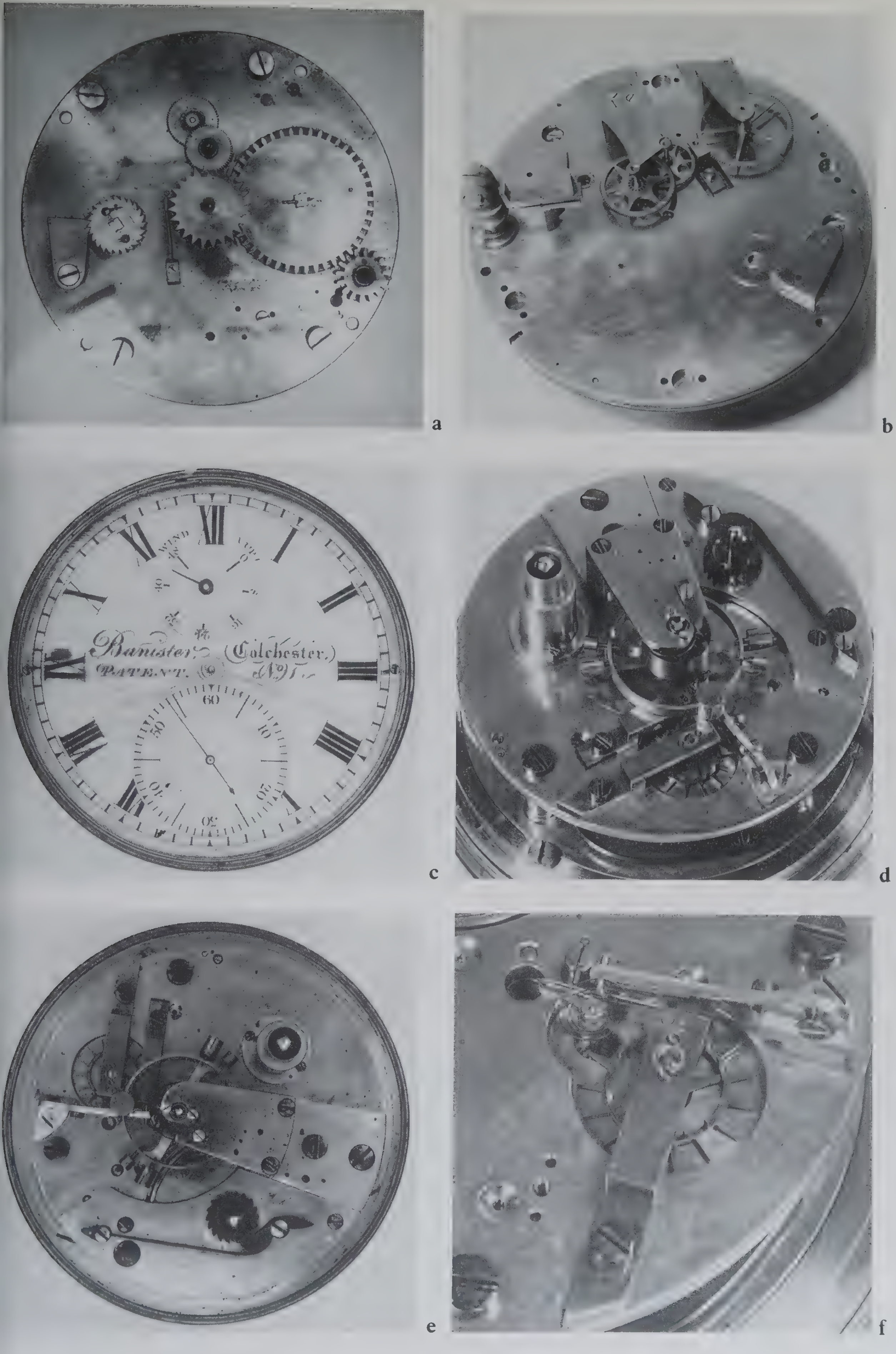
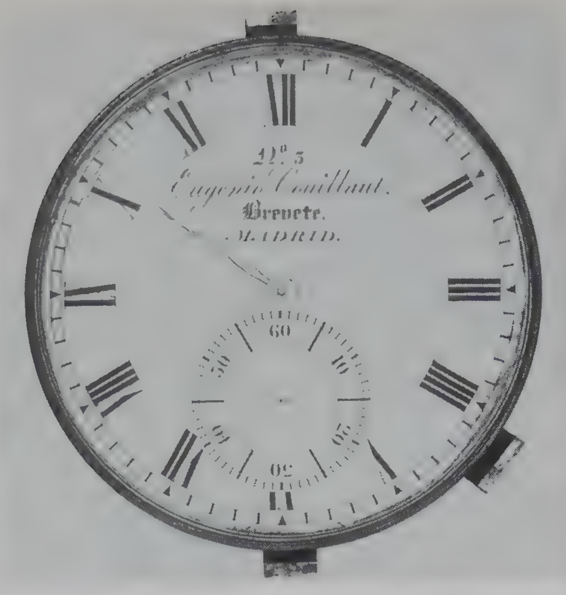

a
b
WIND UP
Banister (Colchester.)
PATENT. No 1
60
10
20
30
40
50
c
d
e
f

Plate 135

a. Cat. no. 170, under dial.
b. Cat. no. 170, underside of the backplate.
c. Cat. no. 171.
d. Cat. no. 171.
e. Cat. no. 171.
f. Cat. no. 171, detail of escapement.

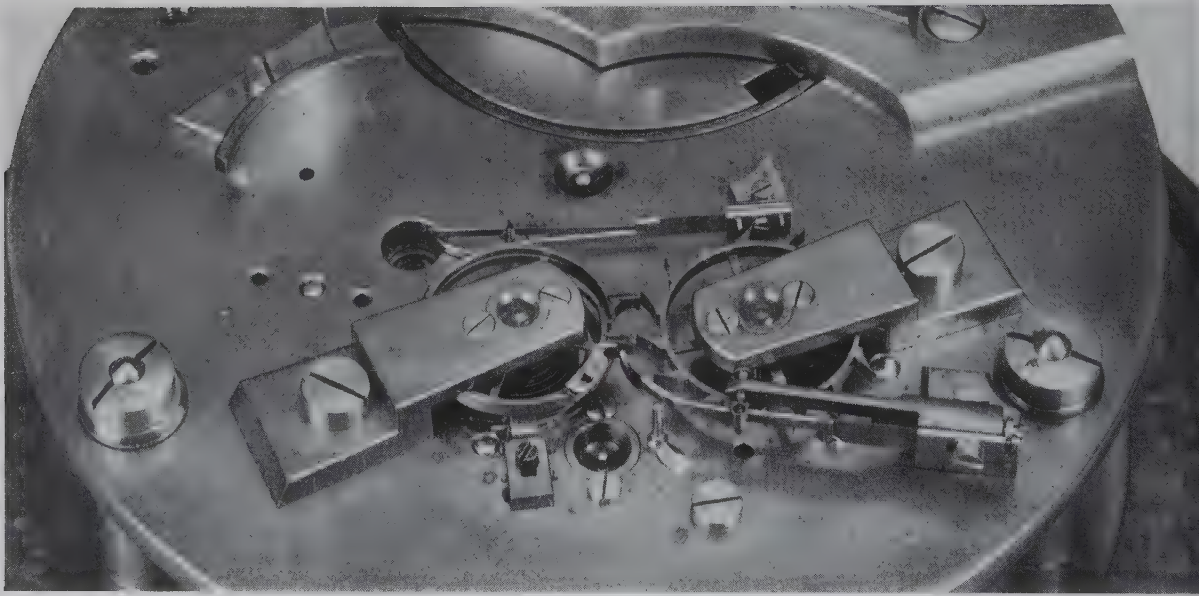
Plate 136

a. Cat. no. 172.
b. Cat. no. 172.
c. Cat. no. 172.
d. Cat. no. 172, balance and escapement.

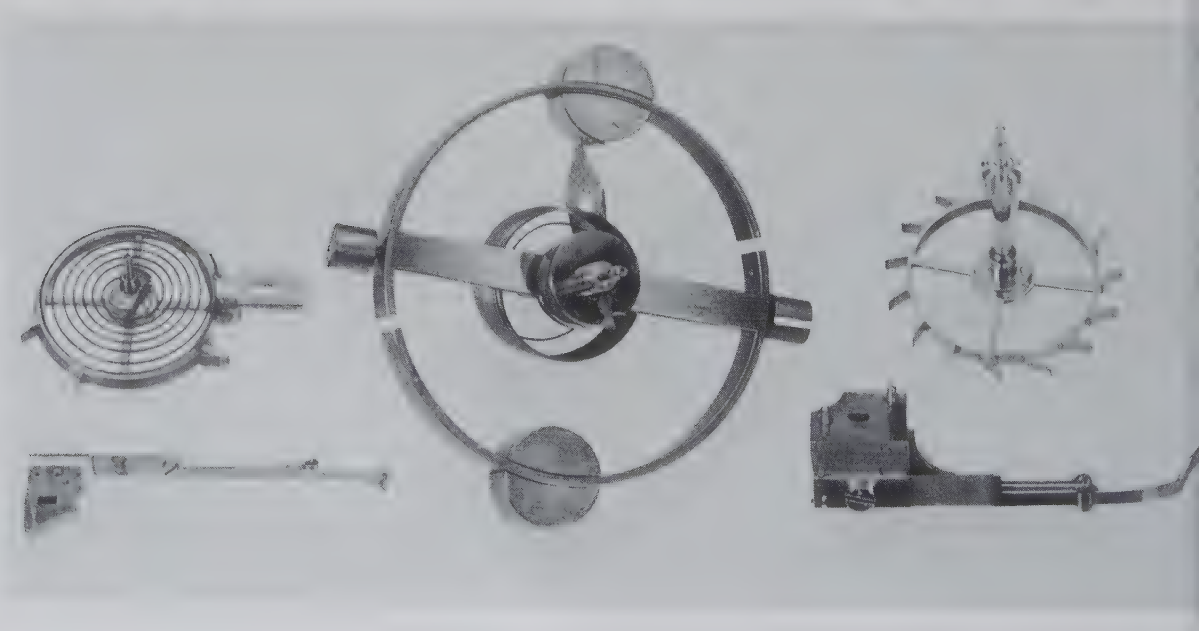

N.º 3
Eugenio Caillaut.
Brevete.
MADRID.
60
10
20
30
40
50

a

b



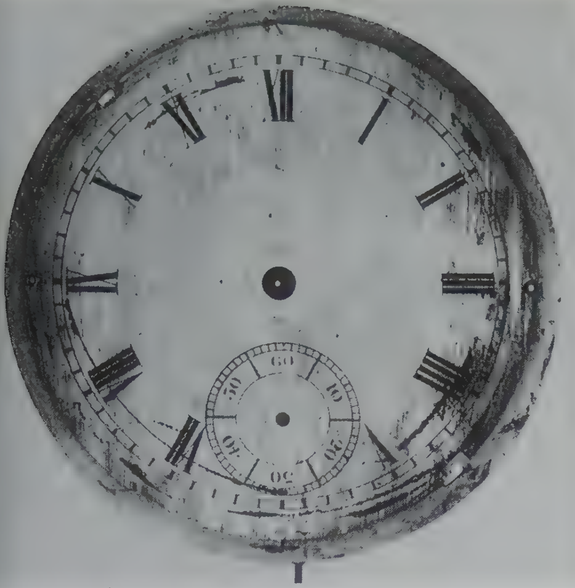
c



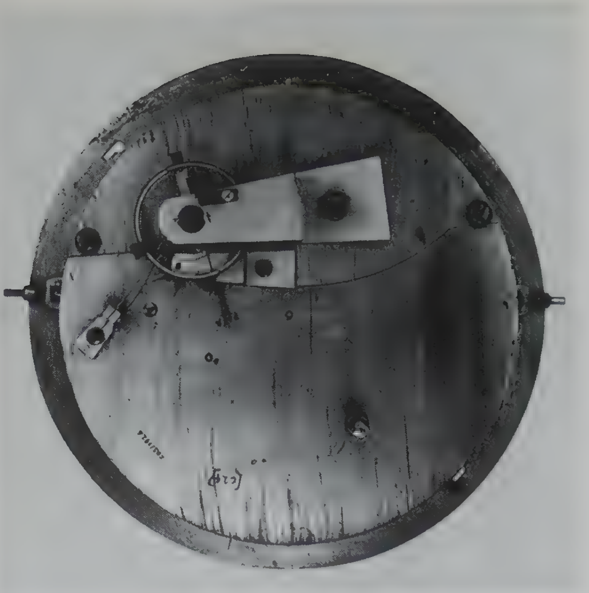
d

Plate 137

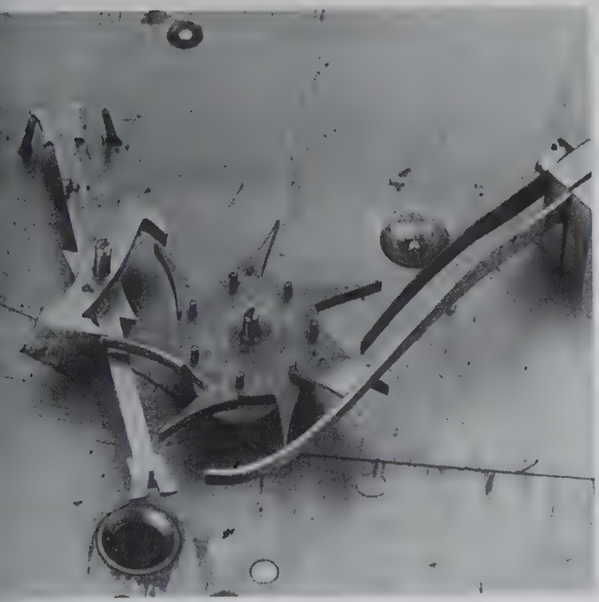
a. Cat. no. 173.
b. Cat. no. 173.
c. Cat. no. 173, constant force escapement.
d. Cat. no. 173.
e. Cat. no. 174.
f. Cat. no. 174.



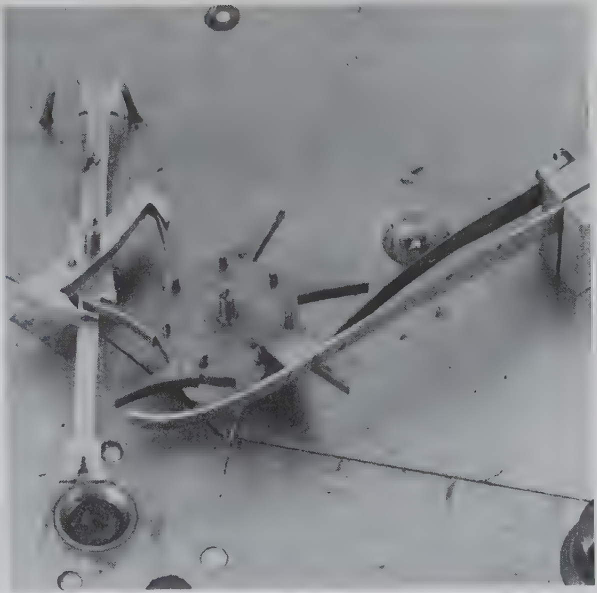
a



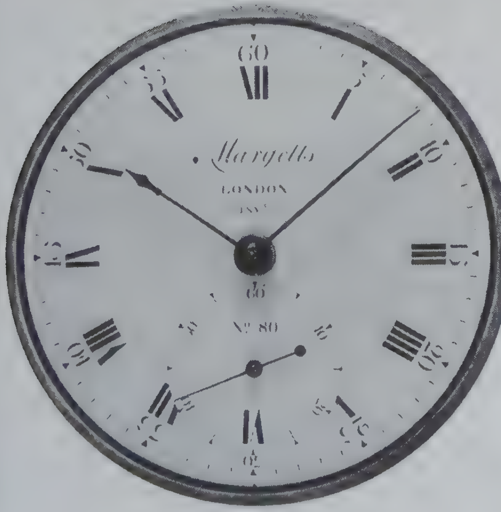
b



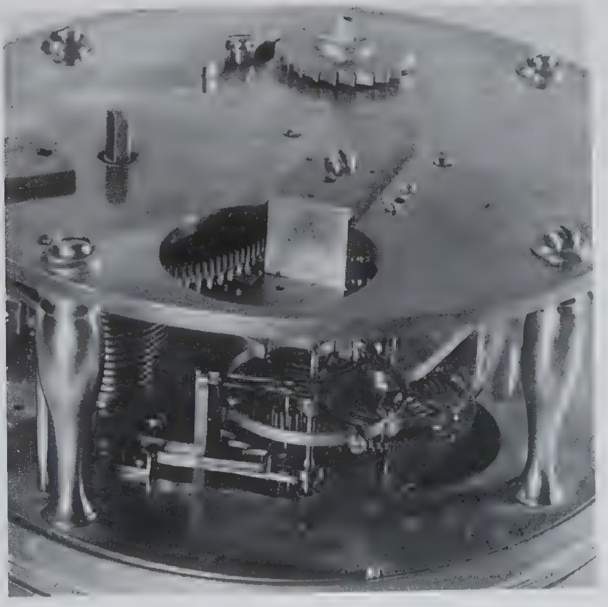
c



d


Margetts
LONDON
INV.
No. 80

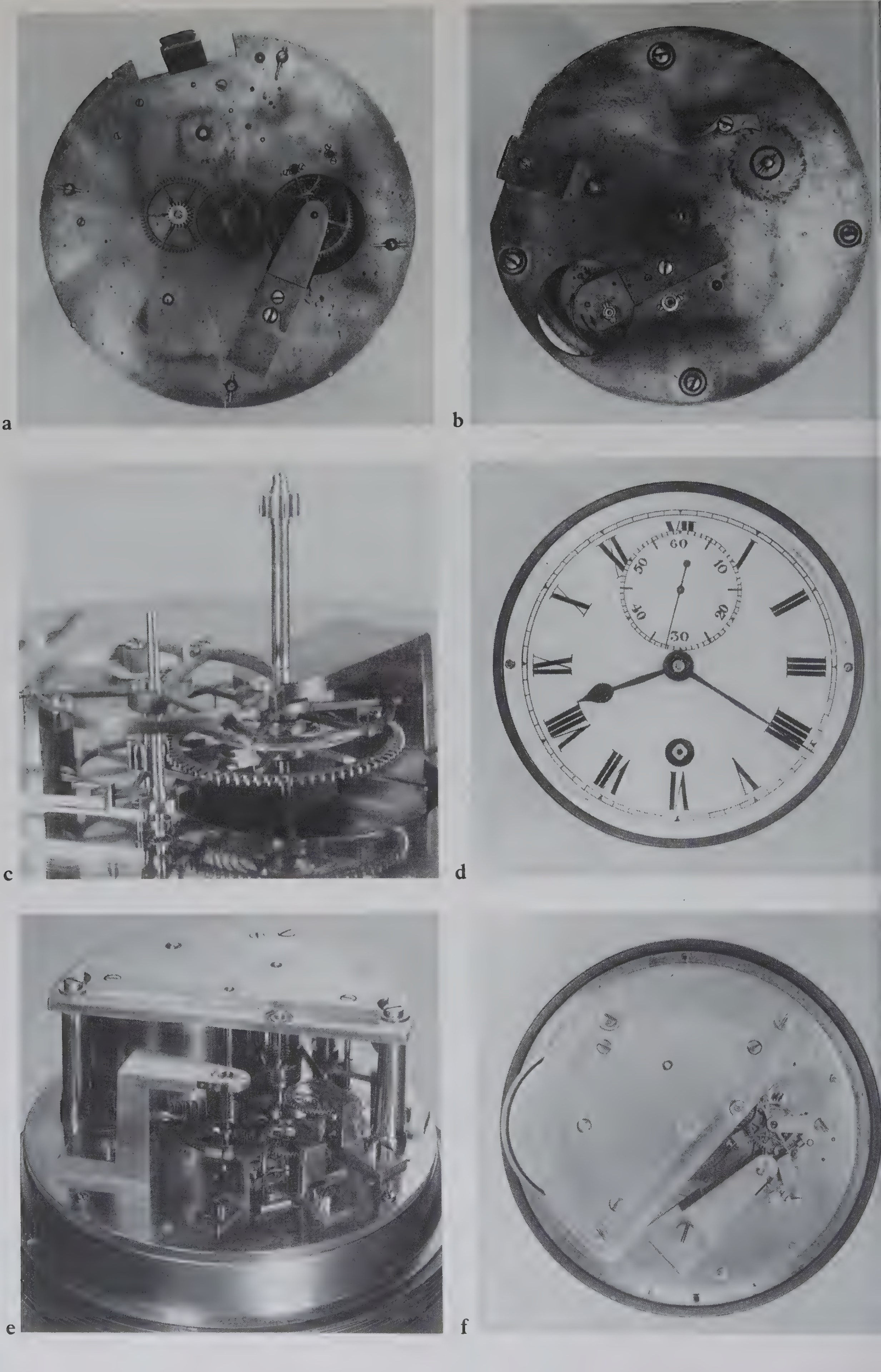
e



f

Plate 138

a. Cat. no. 174.
b. Cat. no. 174.
c. Cat. no. 174.
d. Cat. no. 175.
e. Cat. no. 175.
f. Cat. no. 175.


a
b
c
d
60
10
20
30
40
50
e
f

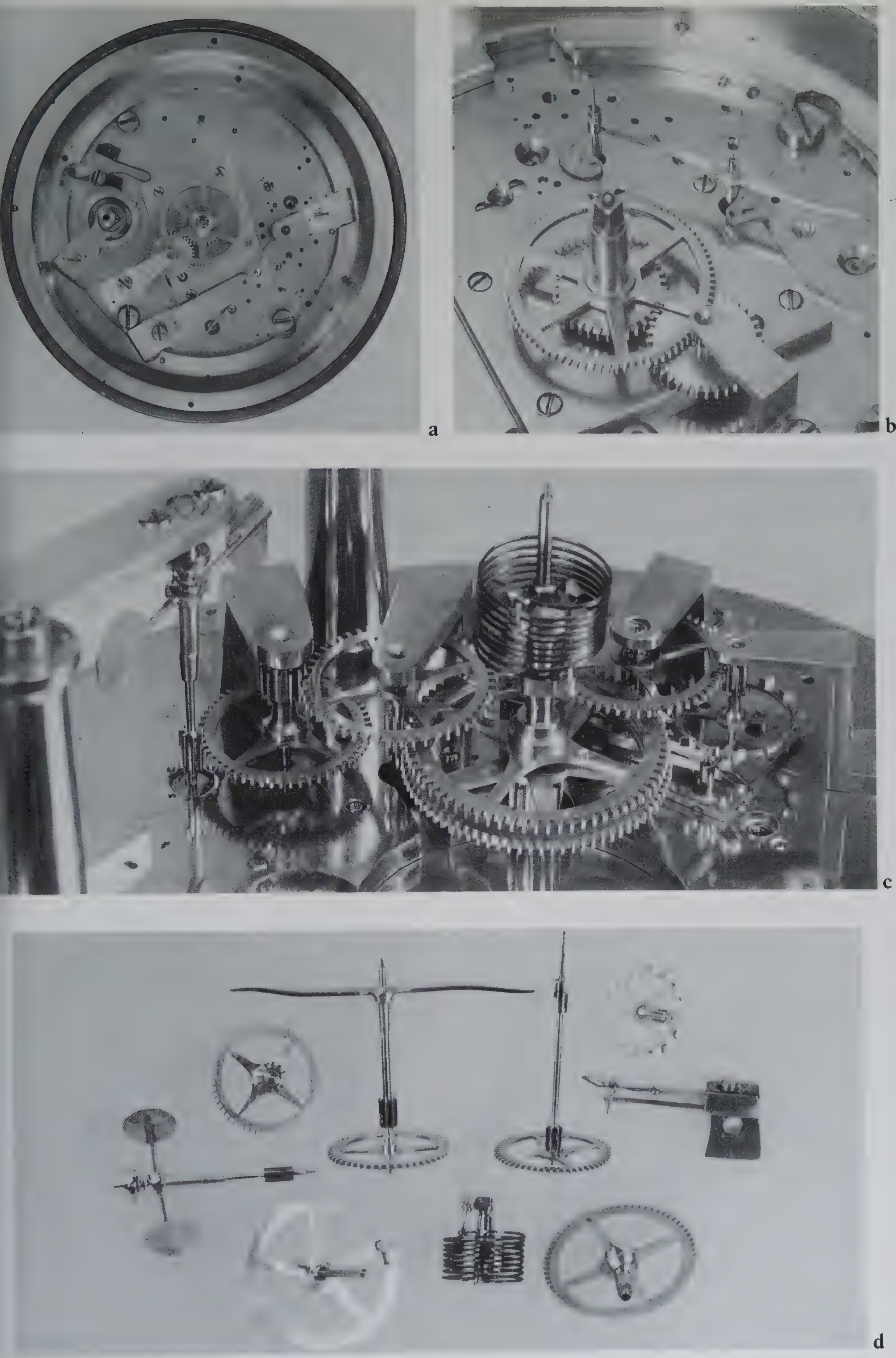
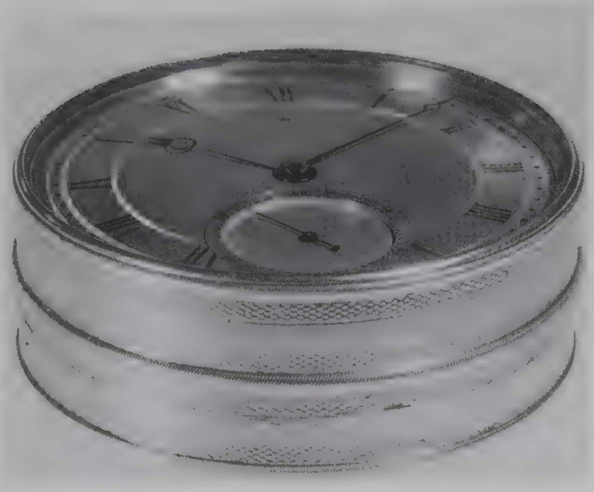


Plate 139

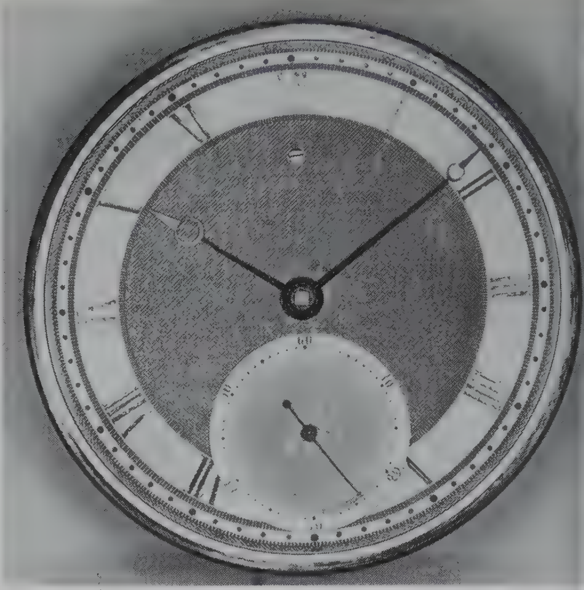
a. Cat. no. 175.
b. Cat. no. 175.
c. Cat. no. 175, constant force escapement.
d. Cat. no. 175, constant force escapement parts.

Plate 140

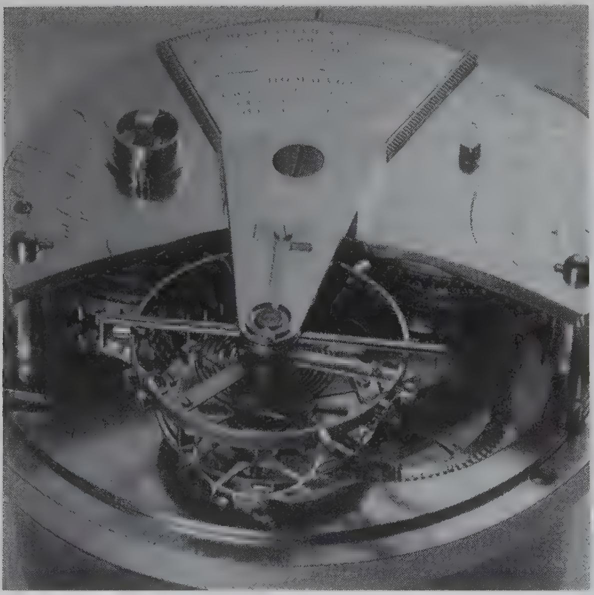
a. Cat. no. 176.
b. Cat. no. 176.
c. Cat. no. 176.
d. Cat. no. 176.
e. Cat. no. 176.
f. Cat. no. 176.
The modifications to the movement plate can be seen.



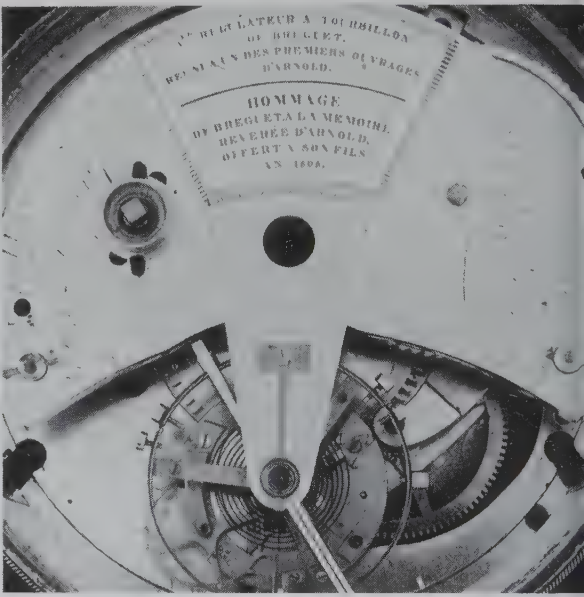
a



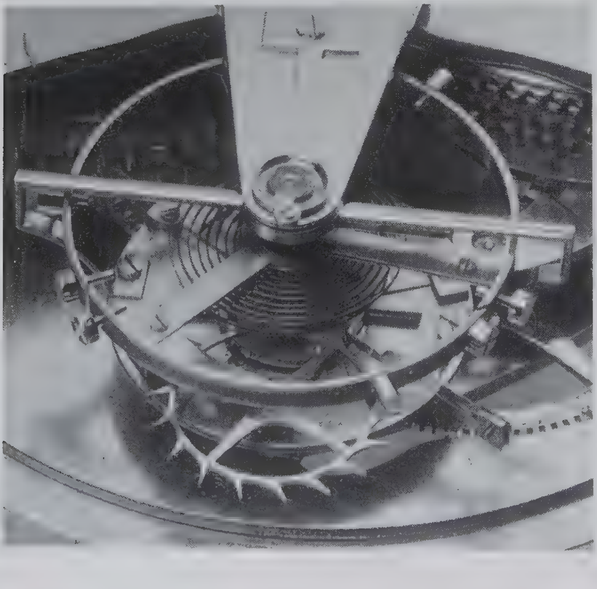
b



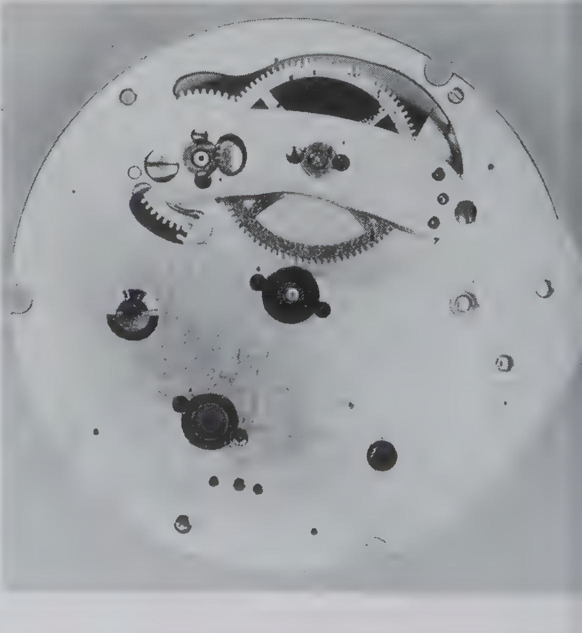
c


1er REGULATEUR A TOURBILLON
DE BREGUET.
REUNI A UN DES PREMIERS OUVRAGES
D'ARNOLD.
HOMMAGE
DE BREGUET A LA MEMOIRE
REVEREE D'ARNOLD,
OFFERT A SON FILS
AN 1808.

d



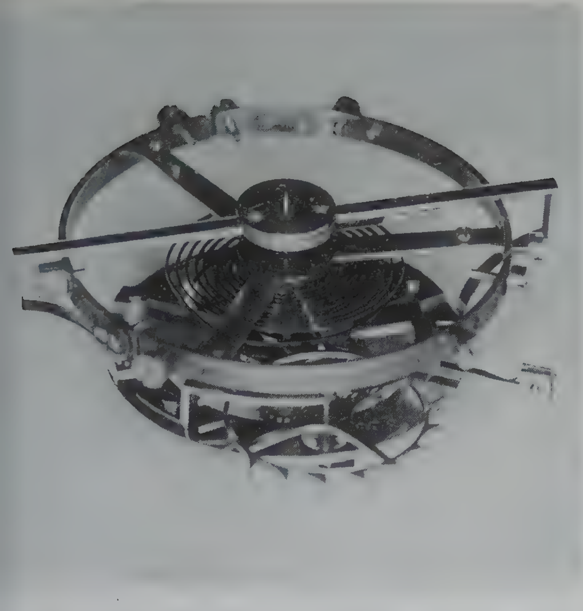
e

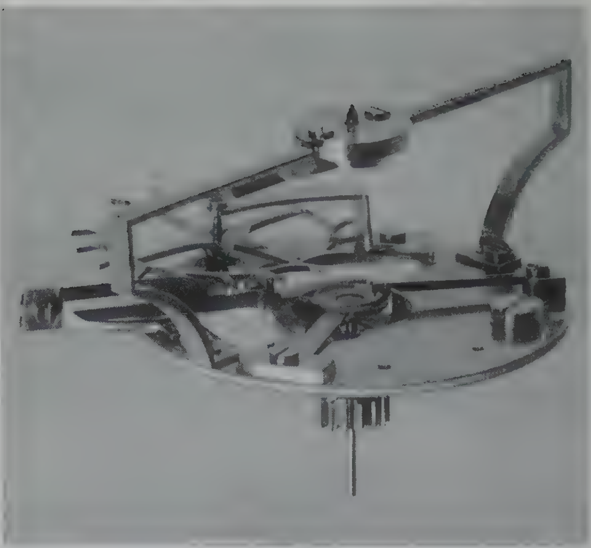


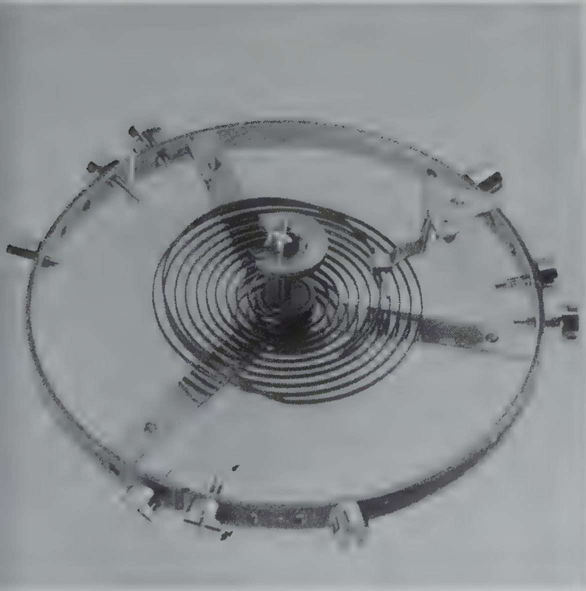
f

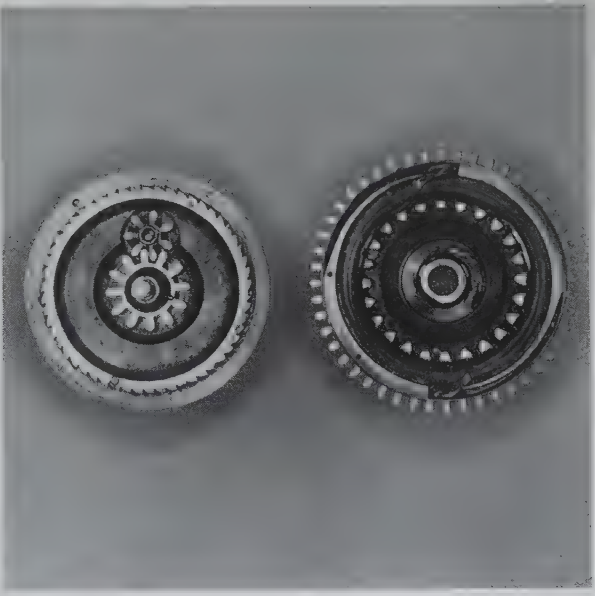
Plate 141

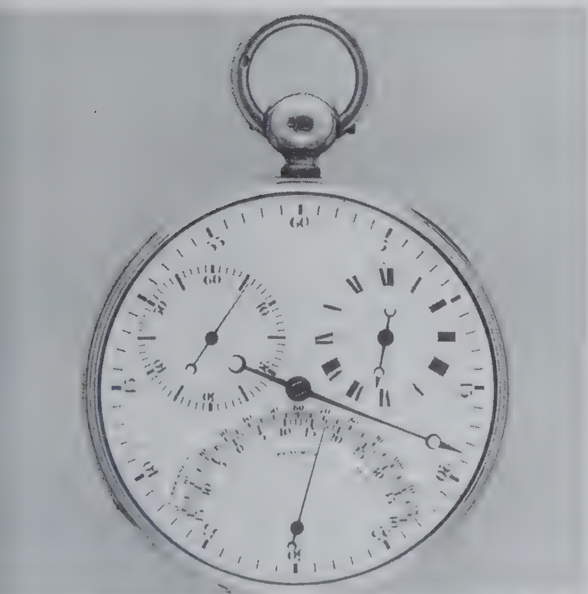
a. Cat. no. 176.
b. Cat. no. 176.
c. Cat. no. 176.
d. Cat. no. 176, Arnold's maintaining power.
e. Cat. no. 177.
f. Cat. no. 177, the thermometer dial of cat. no. 438 in *European Scientific Instruments* by F.A.B. Ward.


a


b


c


d


e

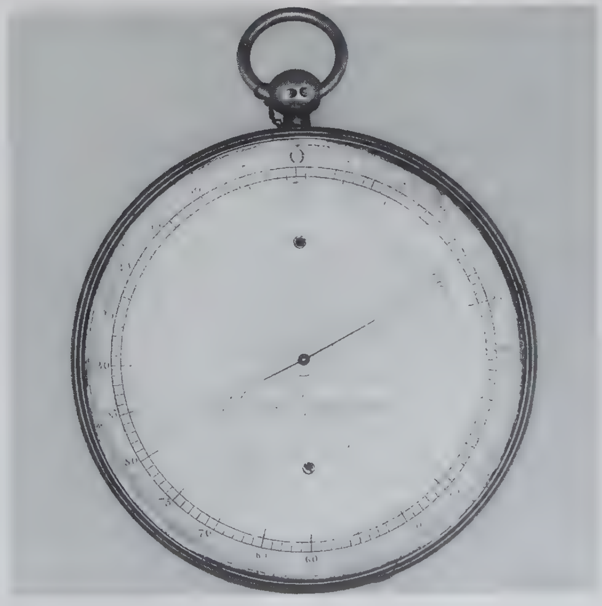

f

Plate 142

a. Cat. no. 177.
b. Cat. no. 177, view showing the 'whiplash' bimetallic strip which operates the thermometer hand.
c. Cat. no. 177, the similar arrangement of the Jurgensen thermometer. *See Pl. 141f.*
d. Cat. no. 177.
e. Cat. no. 177, the tourbillon carriage.
f. Cat. no. 177.

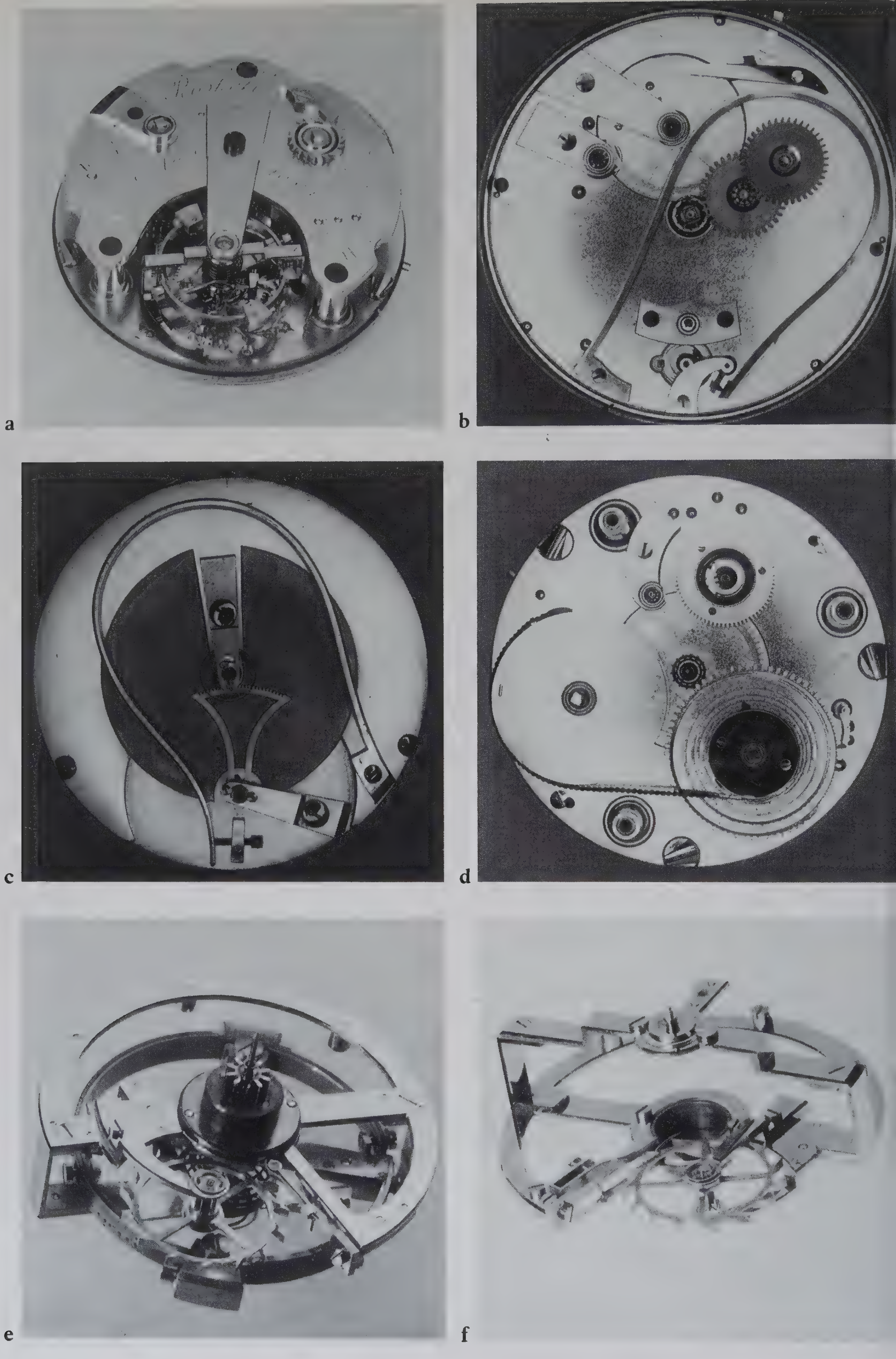
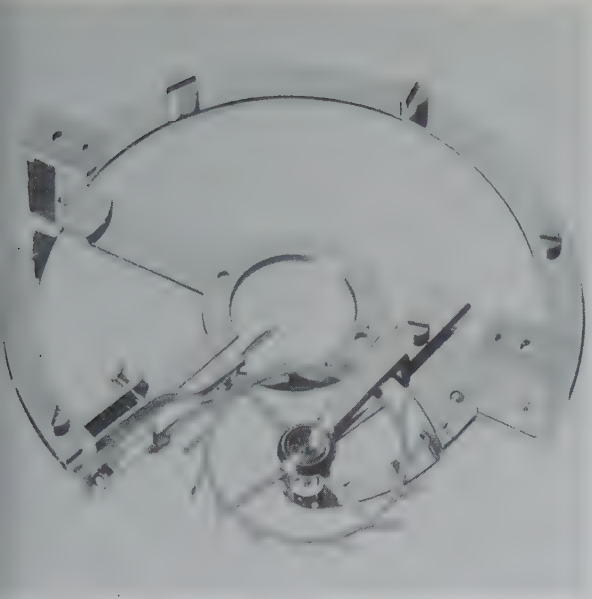
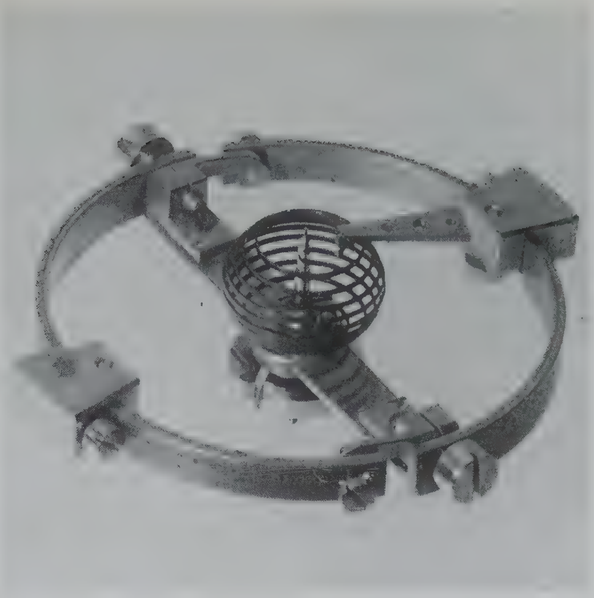
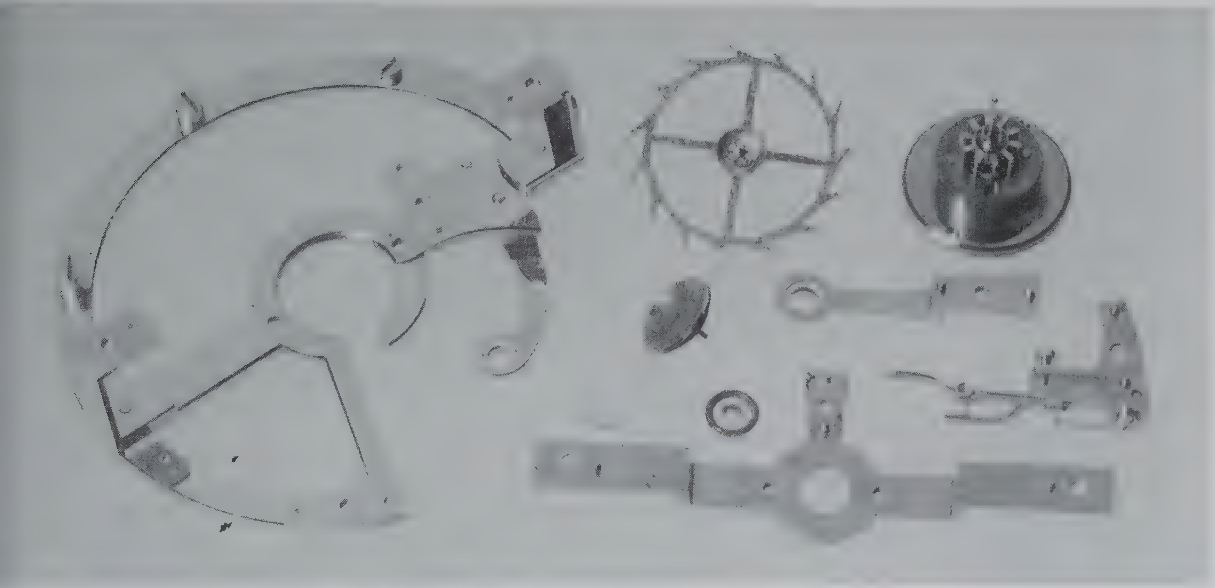


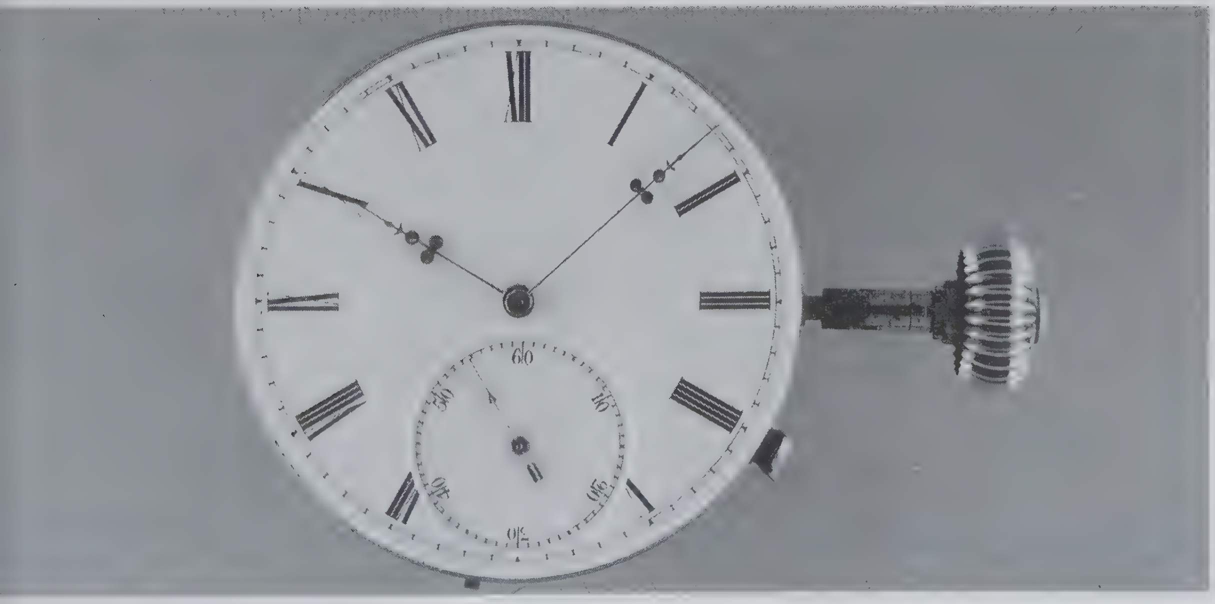
Plate 143

a. Cat. no. 177.
b. Cat. no. 177.
c. Cat. no. 177.
d. Cat. no. 178.


a


b

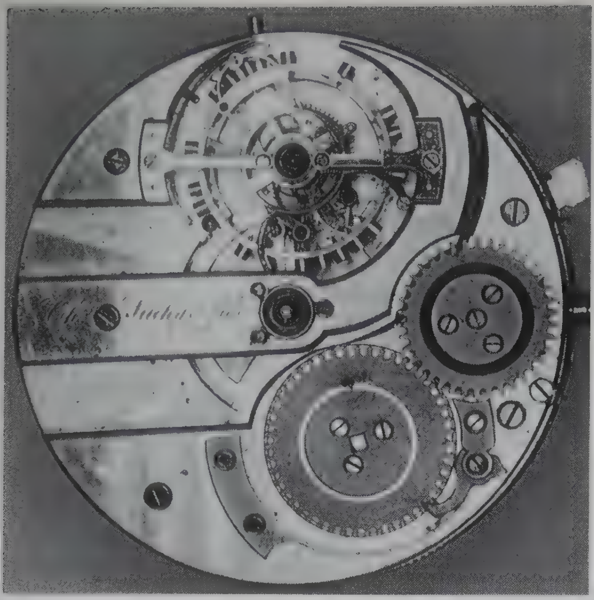

c

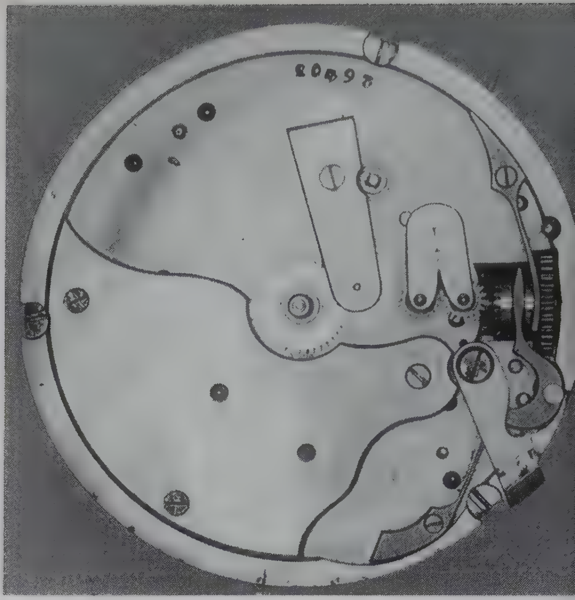

d

60
10
20
30
40
50

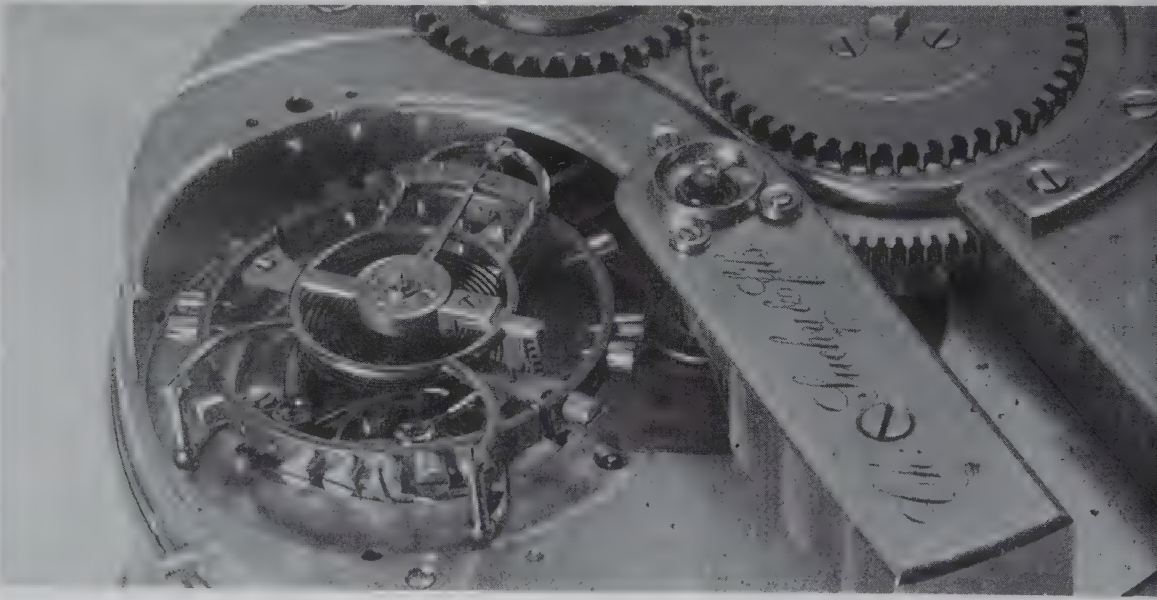
Plate 144

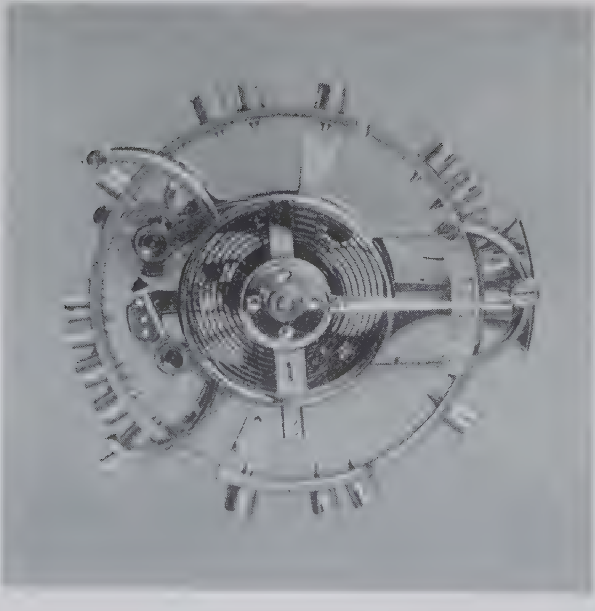
a. Cat. no. 178.
b. Cat. no. 178.
c. Cat. no. 178.
d. Cat. no. 178.
e. Cat. no. 178.


a



b


c


d

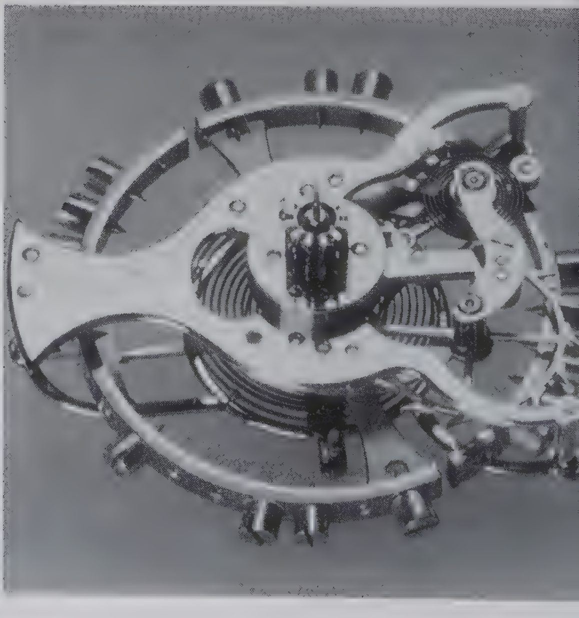
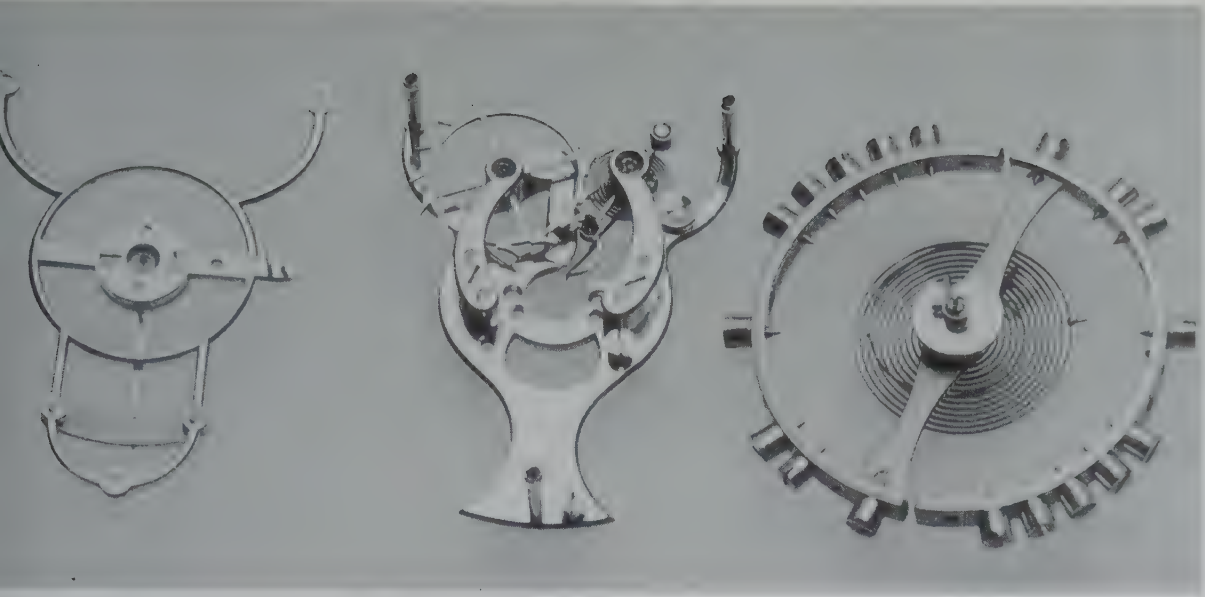
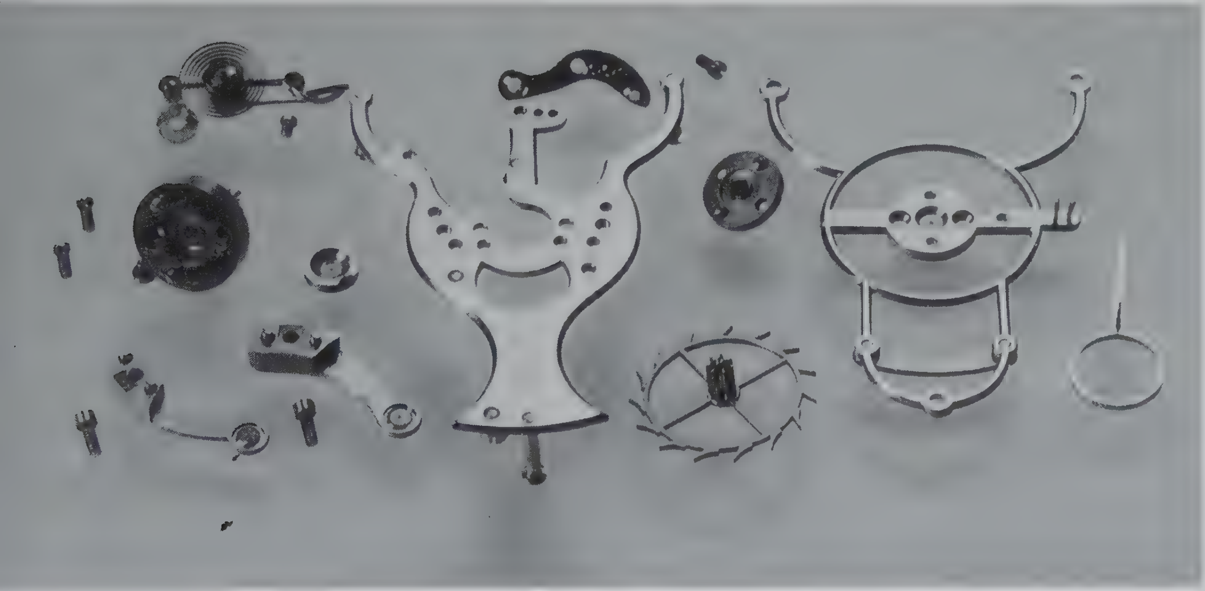

e

Plate 145

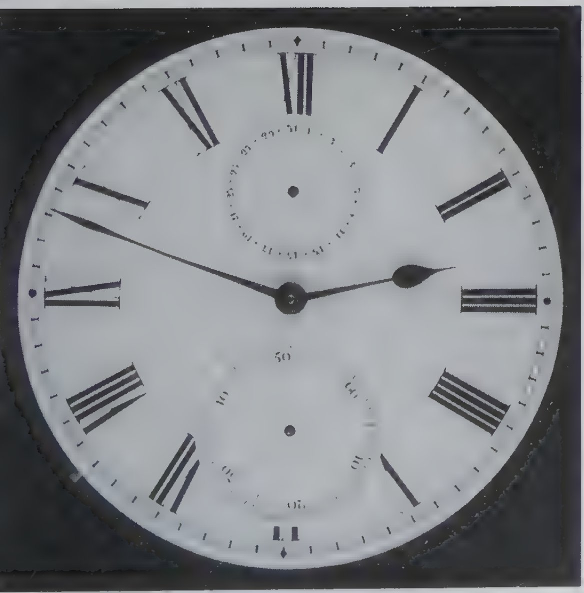
a. Cat. no. 178.
b. Cat. no. 178.
c. Cat. no. 179.
d. Cat. no. 179.



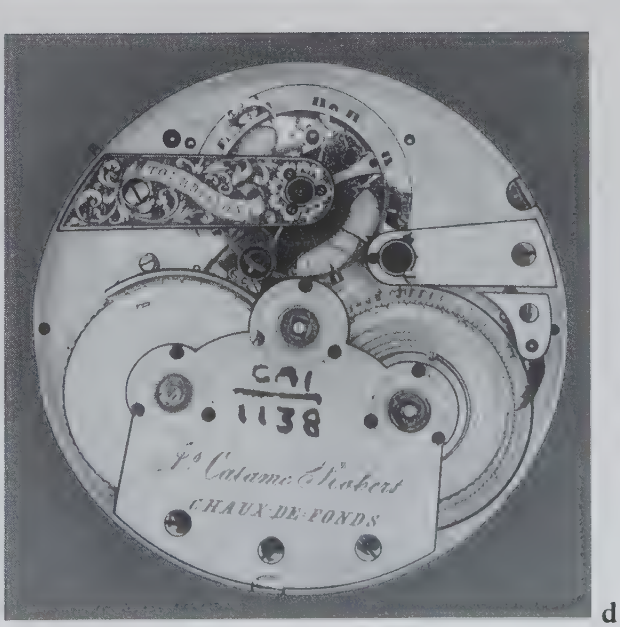
a



b



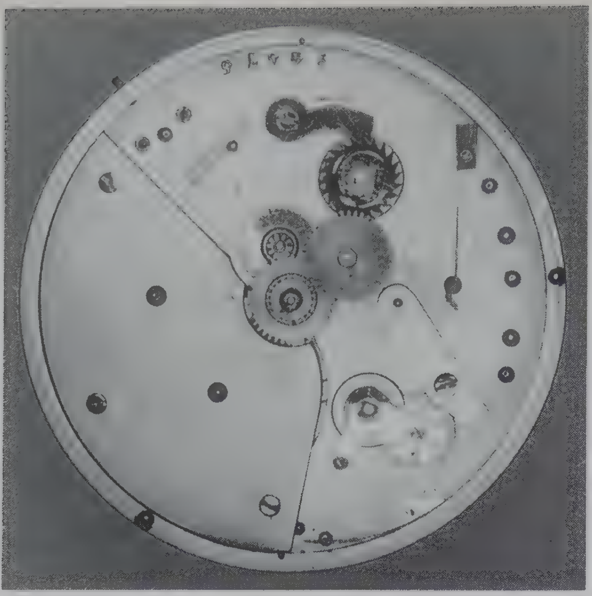
c


GA1
1138
Fs Catame & Robert
CHAUX-DE-FONDS

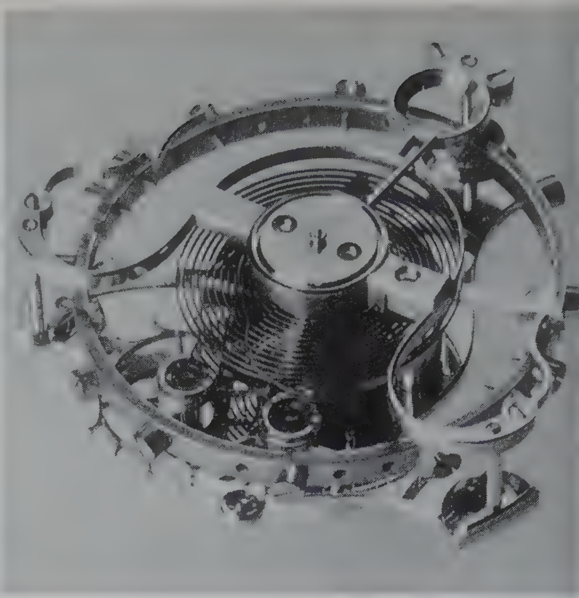
d

Plate 146

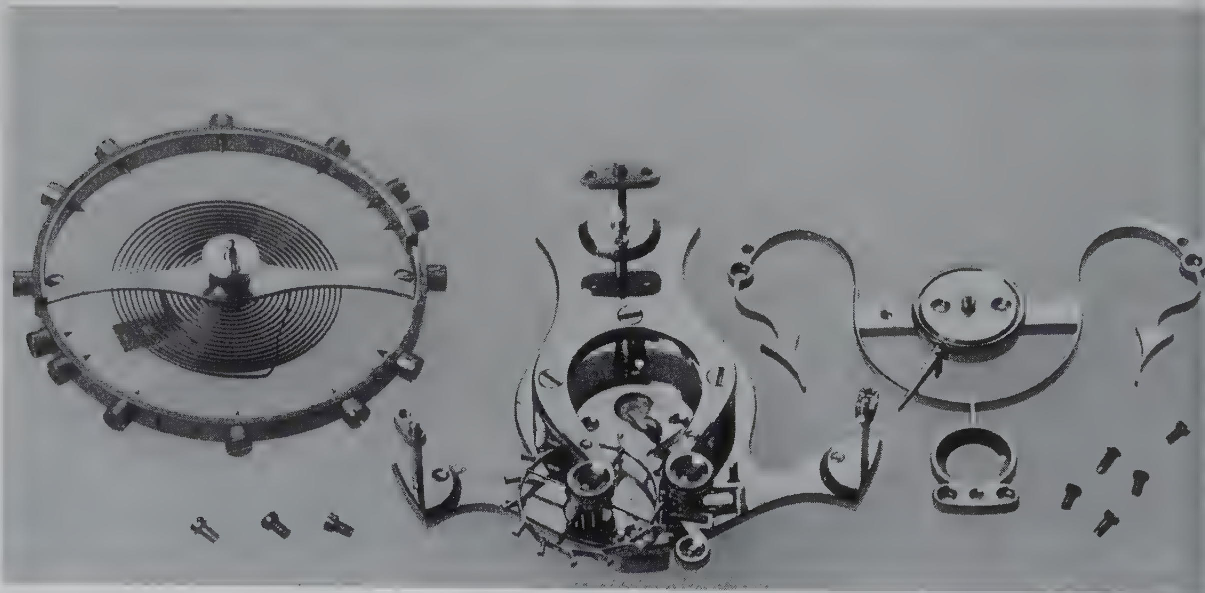
a. Cat. no. 179.
b. Cat. no. 179.
c. Cat. no. 179.
d. Cat. no. 179.



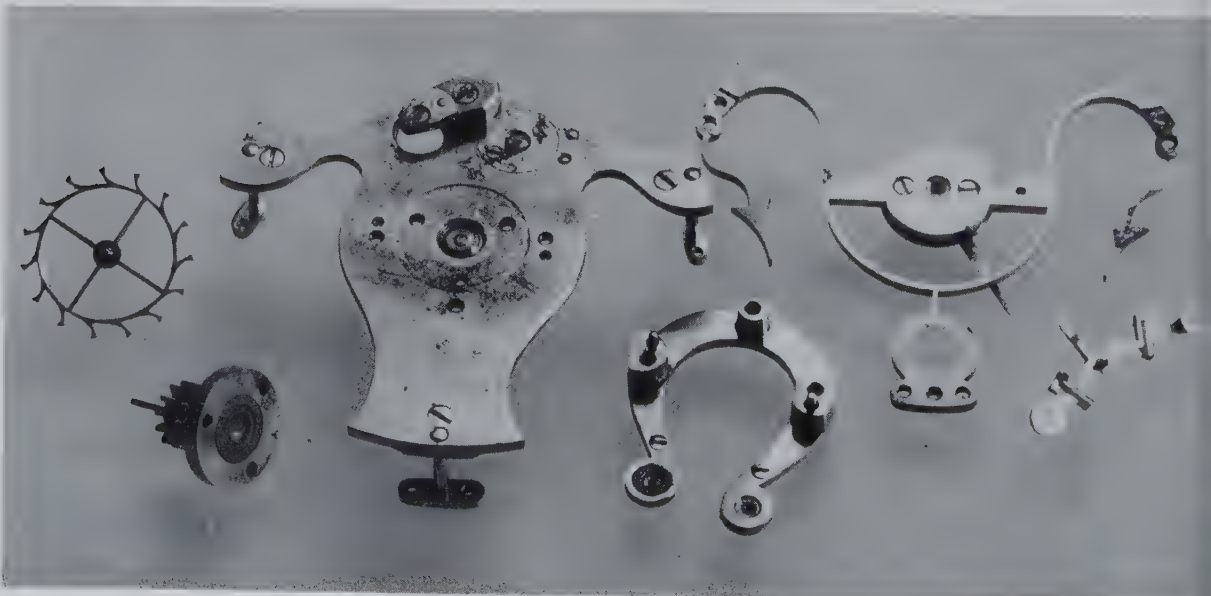
a



b



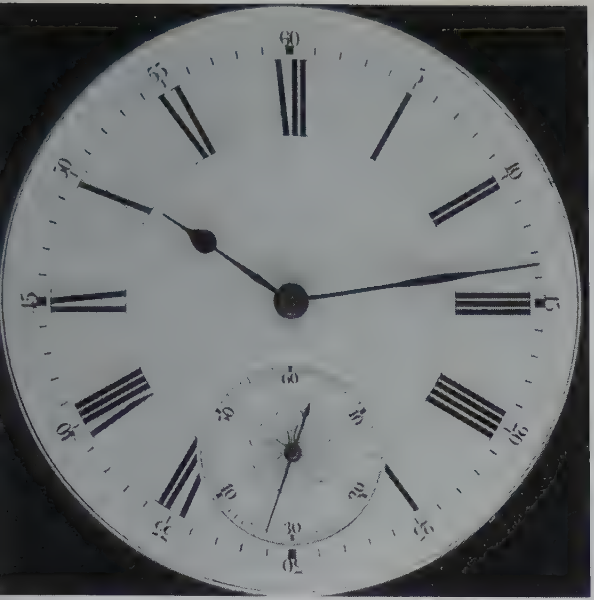
c

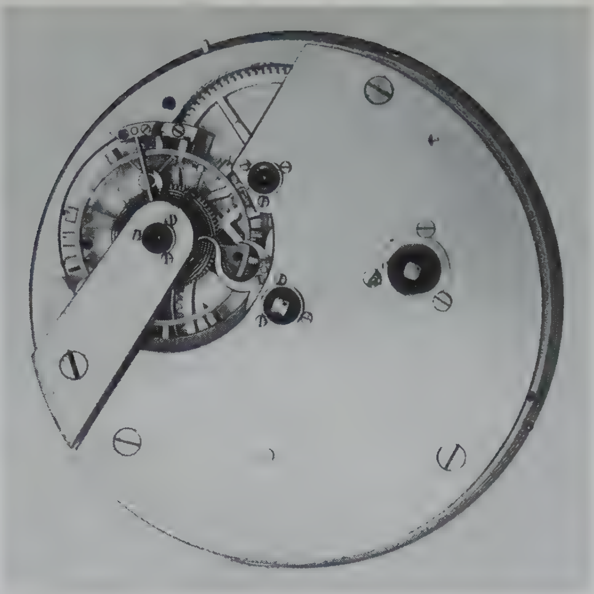


d

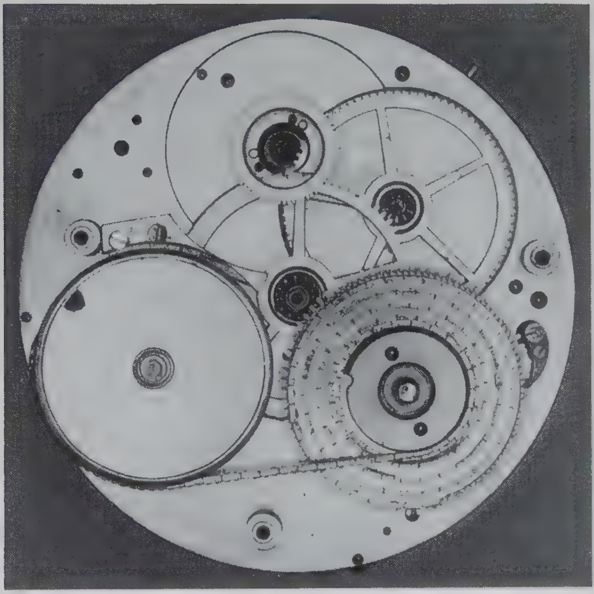
Plate 147

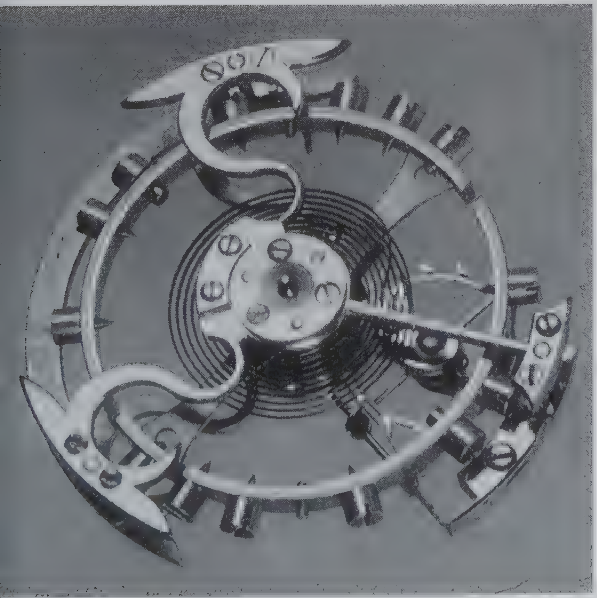
a. Cat. no. 180.
b. Cat. no. 180.
c. Cat. no. 180.
d. Cat. no. 180, backplate removed.
e. Cat. no. 180.
f. Cat. no. 180.


a


b

c


d


e

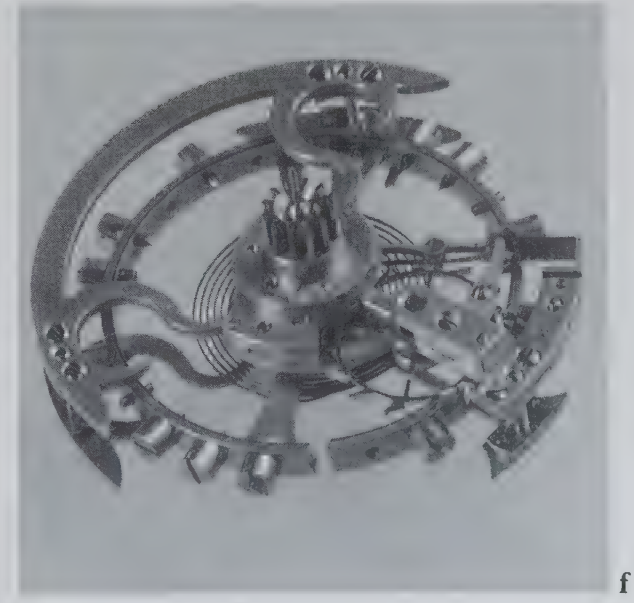
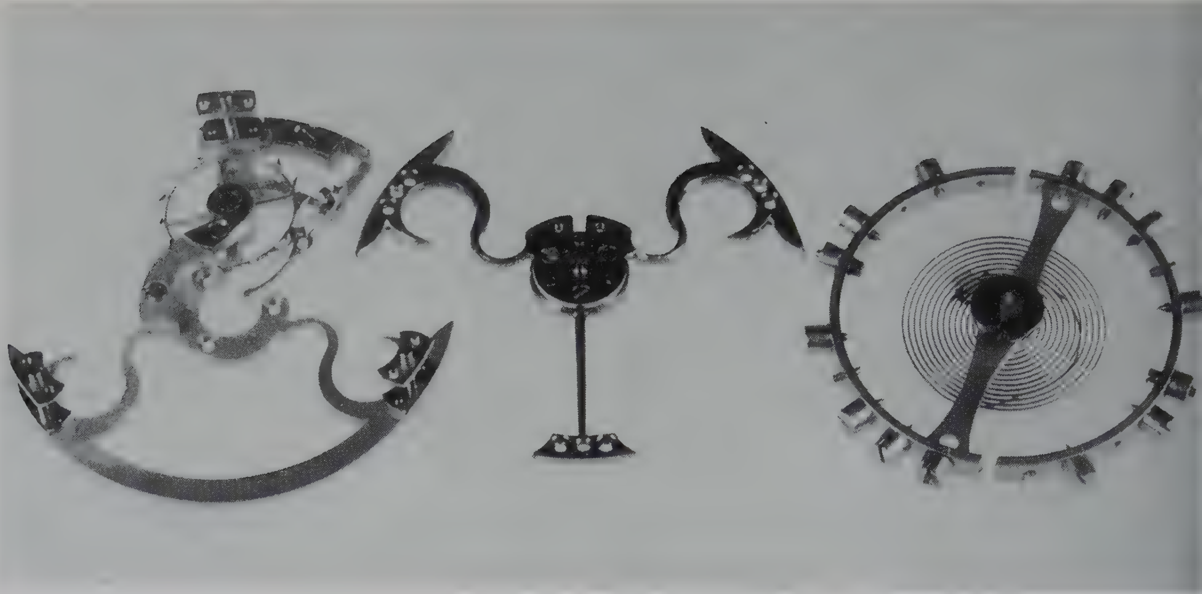
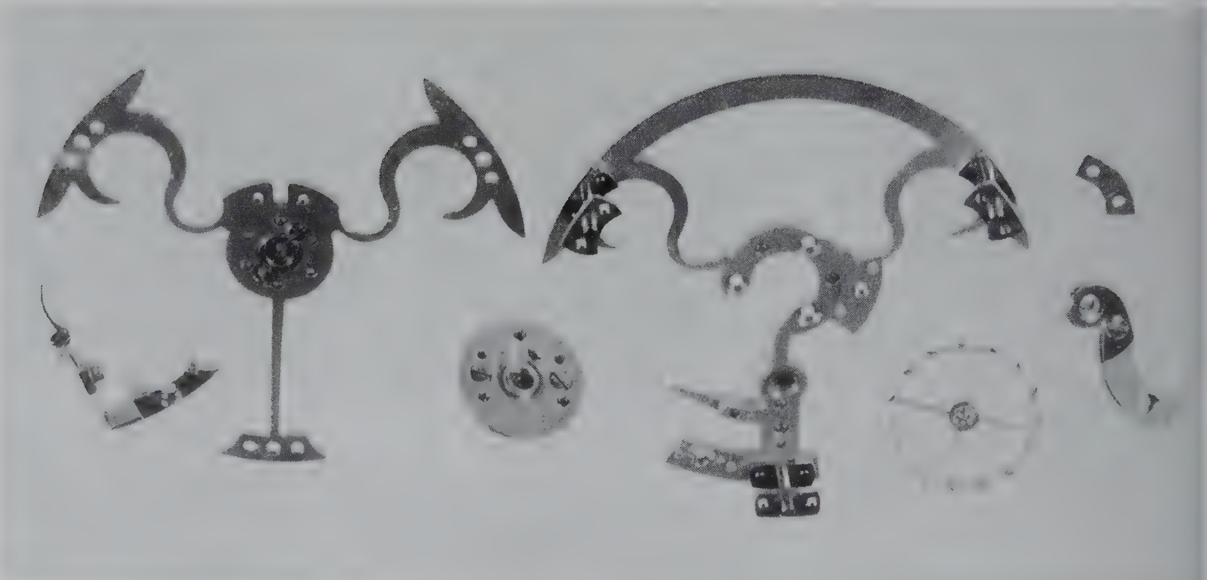

f

Plate 148

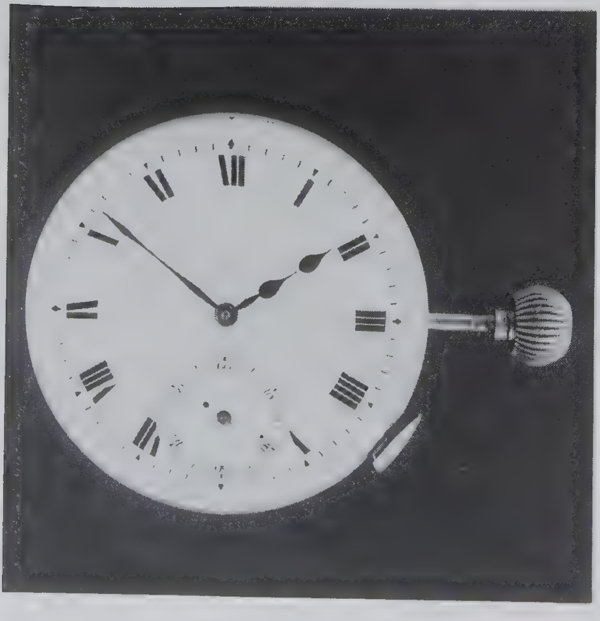
a. Cat. no. 180.
b. Cat. no. 180.
c. Cat. no. 181.
d. Cat. no. 181.



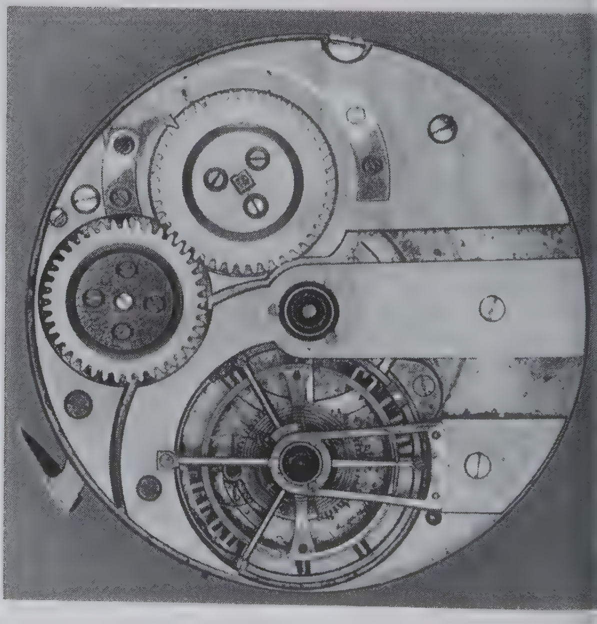
a



b



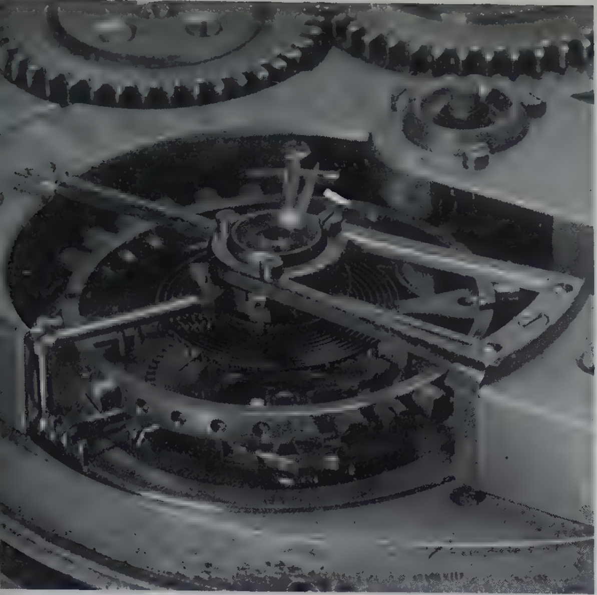
c



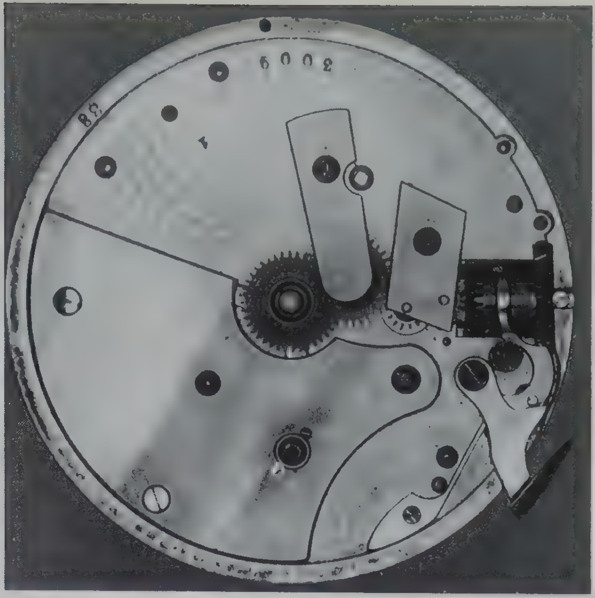
d

Plate 149

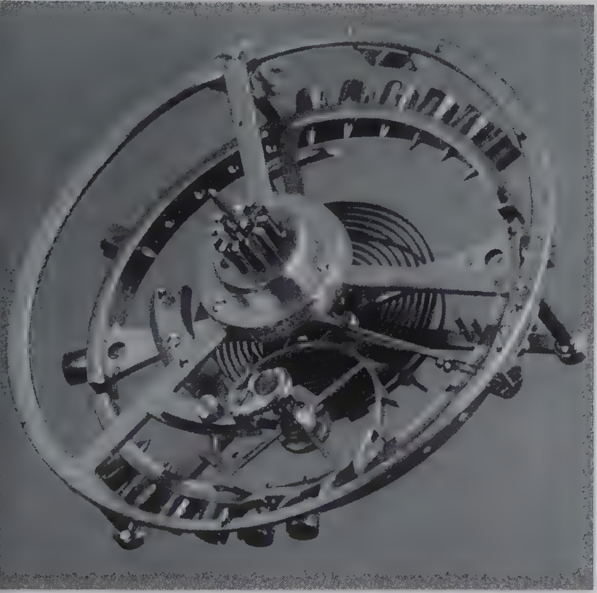
a. Cat. no. 181.
b. Cat. no. 181.
c. Cat. no. 181.
d. Cat. no. 181.
e. Cat. no. 182.
f. Cat. no. 182.



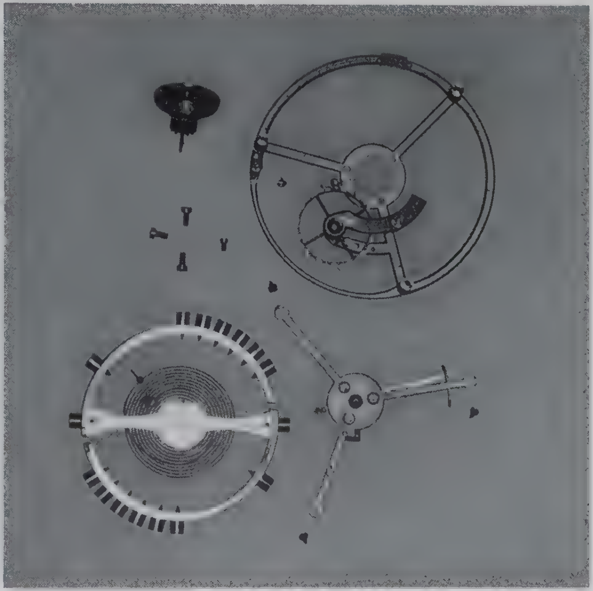
a



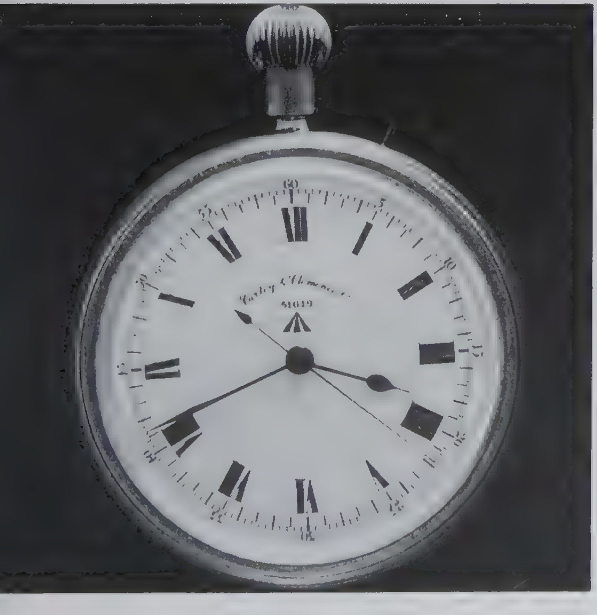
b



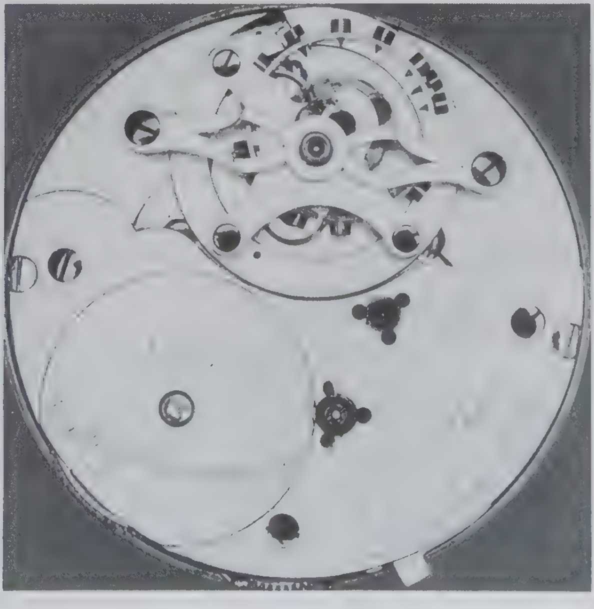
c



d



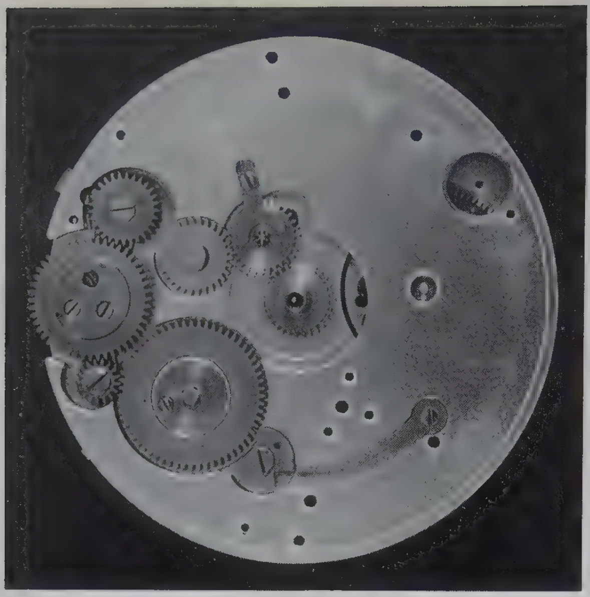
e

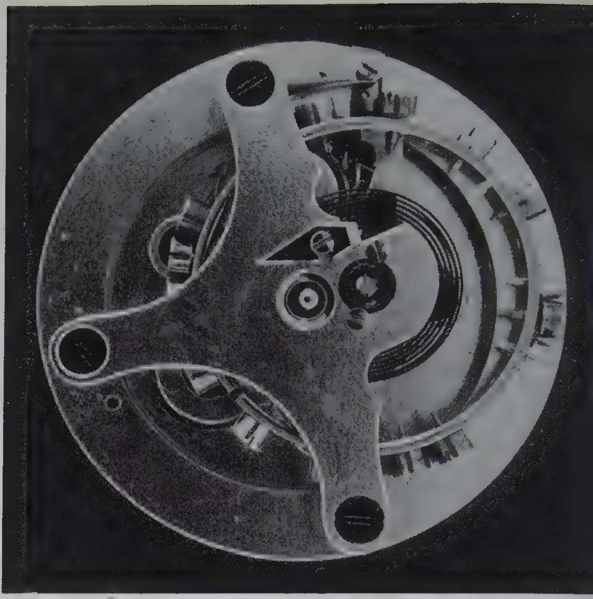


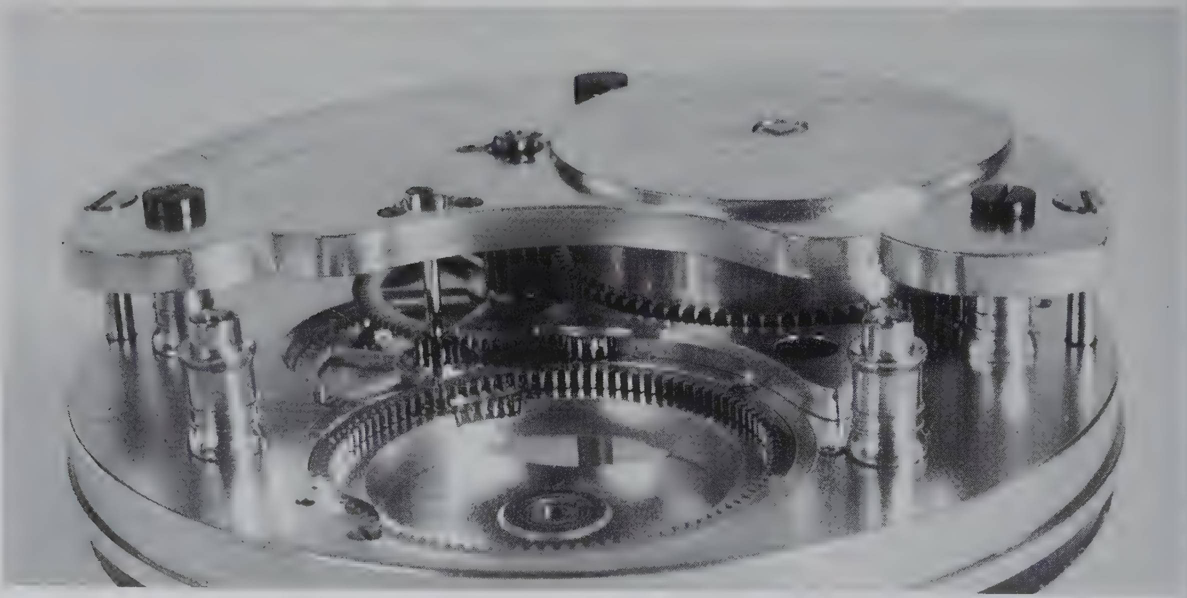
f

Plate 150

a. Cat. no. 182.
b. Cat. no. 182.
c. Cat. no. 182.
d. Cat. no. 182.


a


b


c

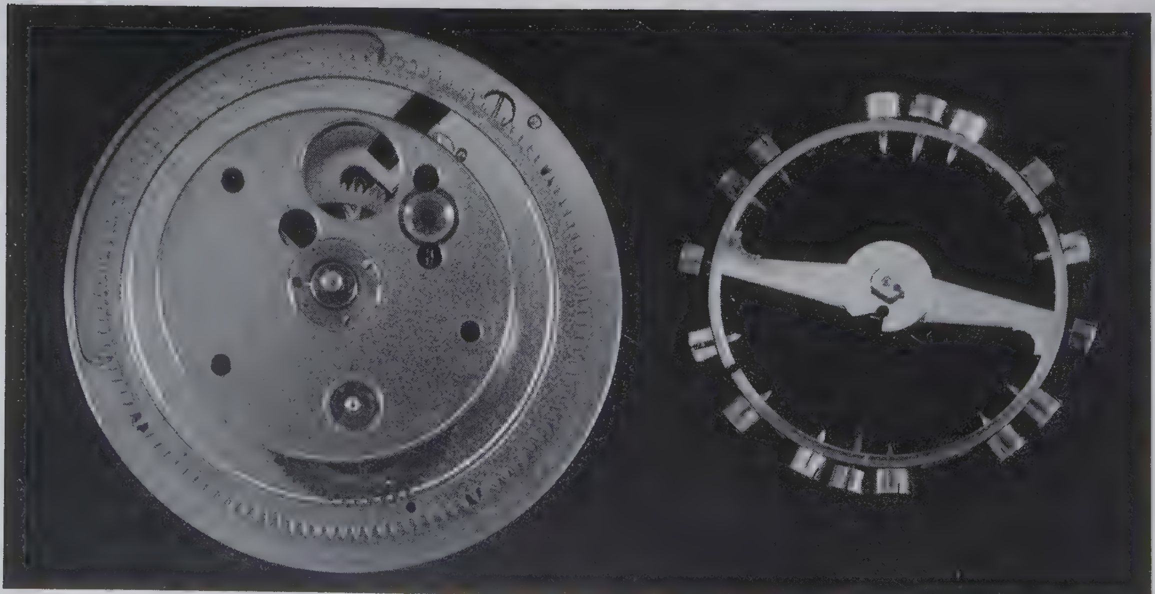
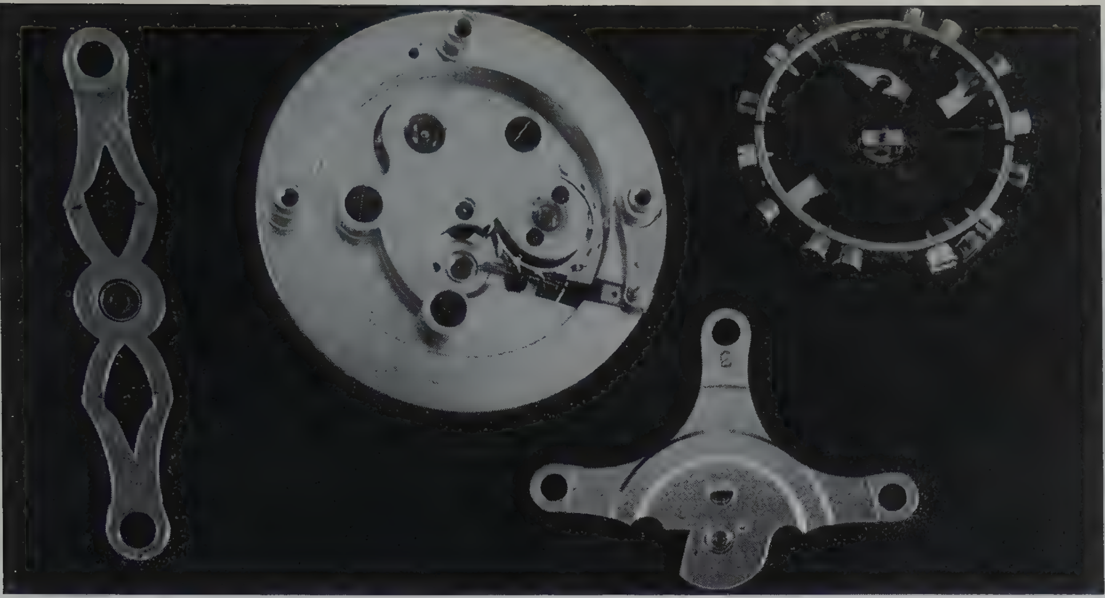
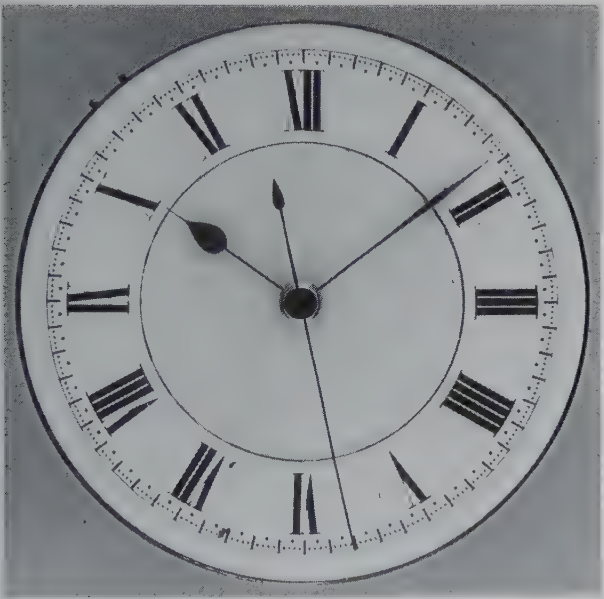
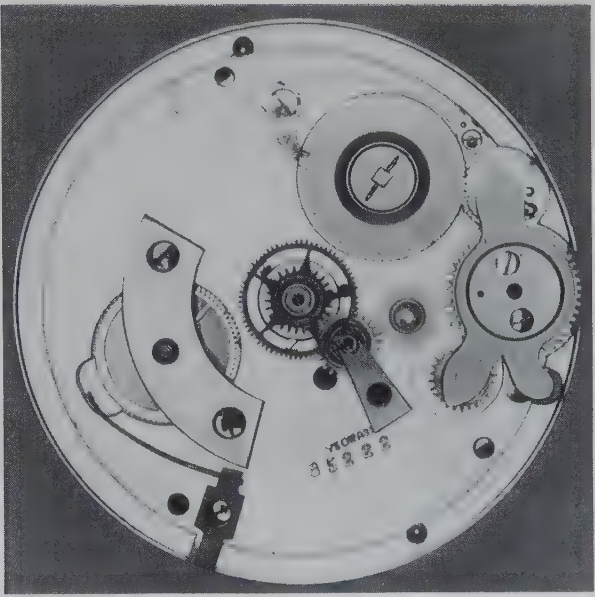

d

Plate 151

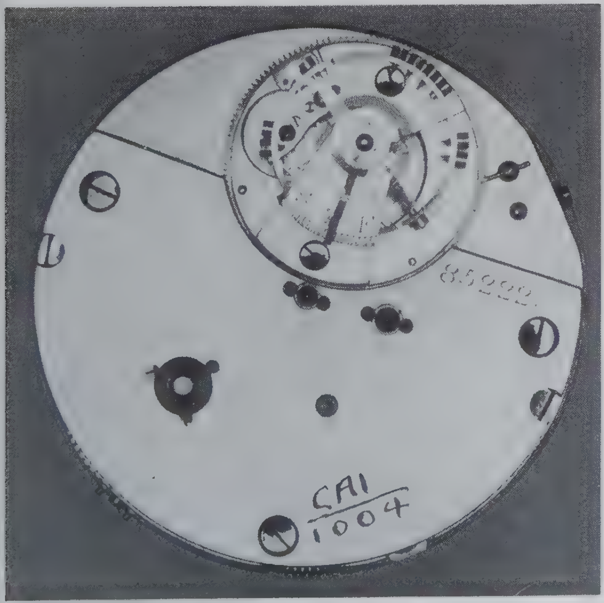
a. Cat. no. 182.
b. Cat. no. 183.
c. Cat. no. 183.
d. Cat. no. 183.
e. Cat. no. 183, balance cock, balance, escapement cock and backplate removed.


a


b



c


85222
CAI
1004
d

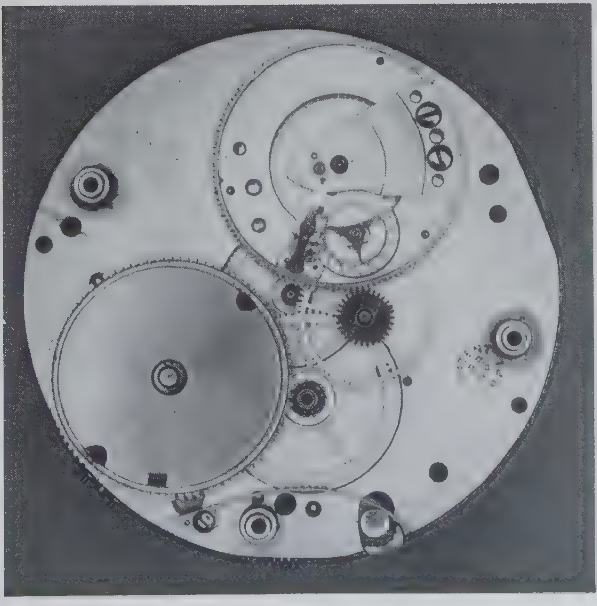
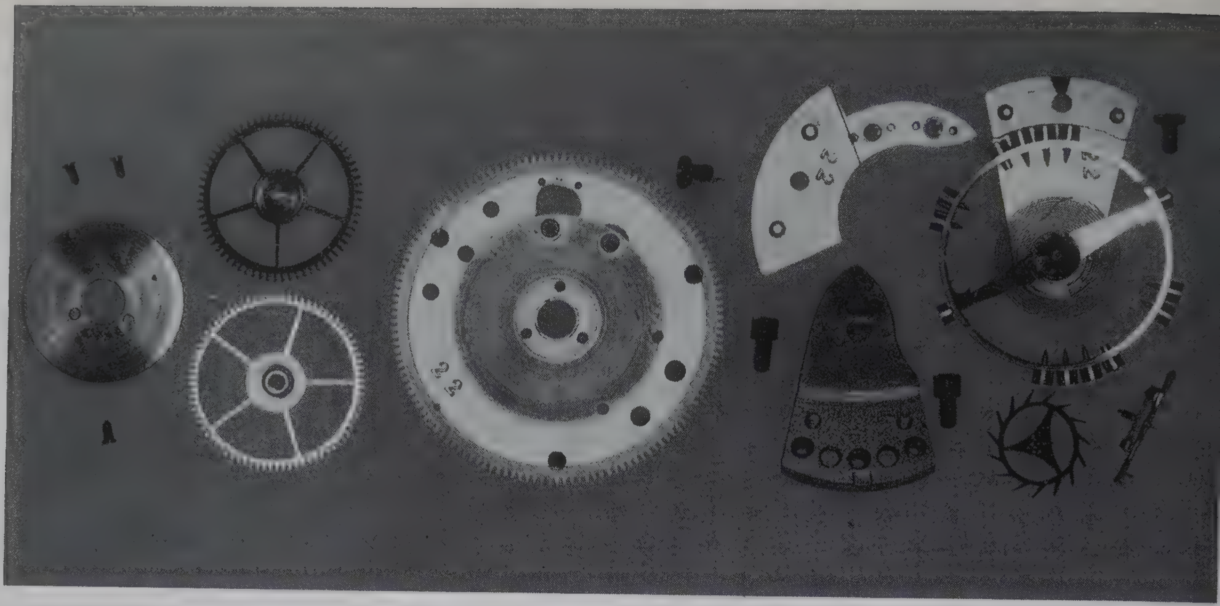
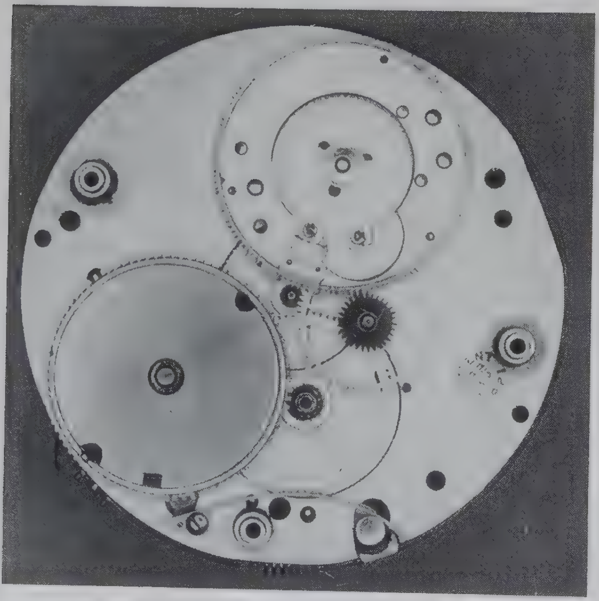
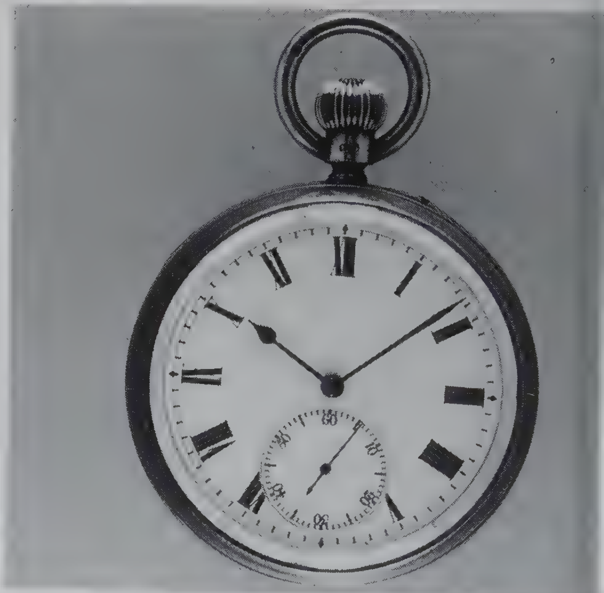

e

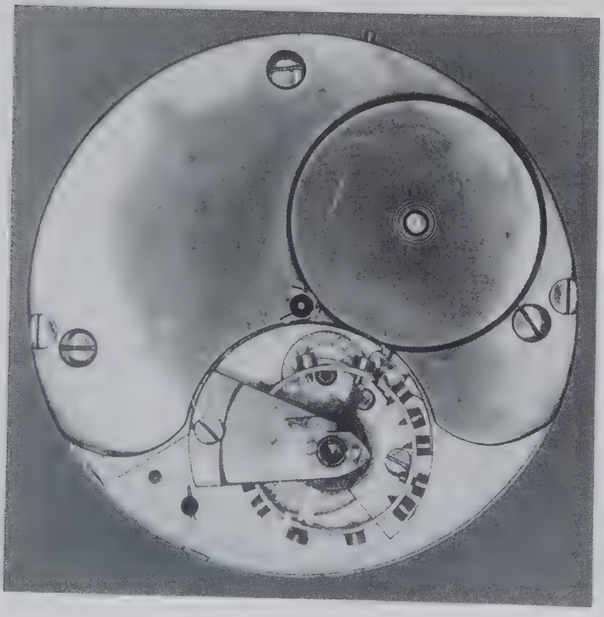
Plate 152

a. Cat. no. 183.
b. Cat. no. 183.
c. Cat. no. 184.
d. Cat. no. 184.
e. Cat. no. 184.


a


b


c


d

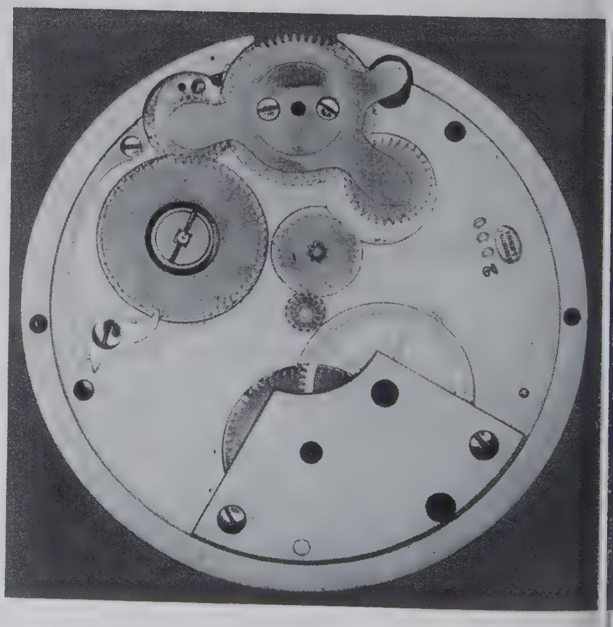
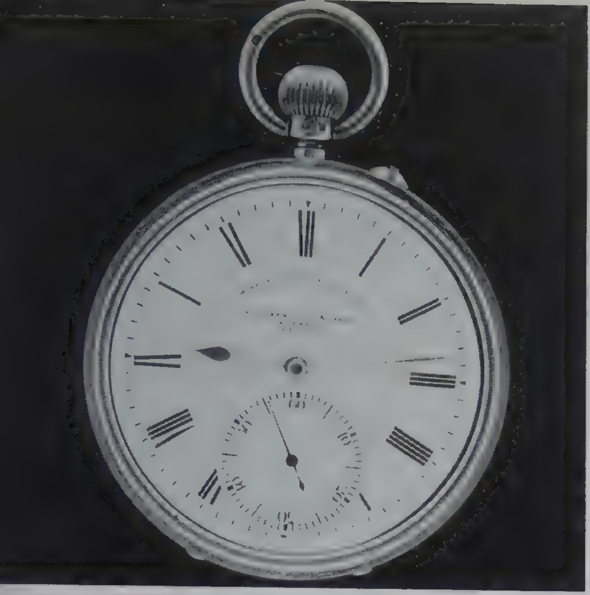
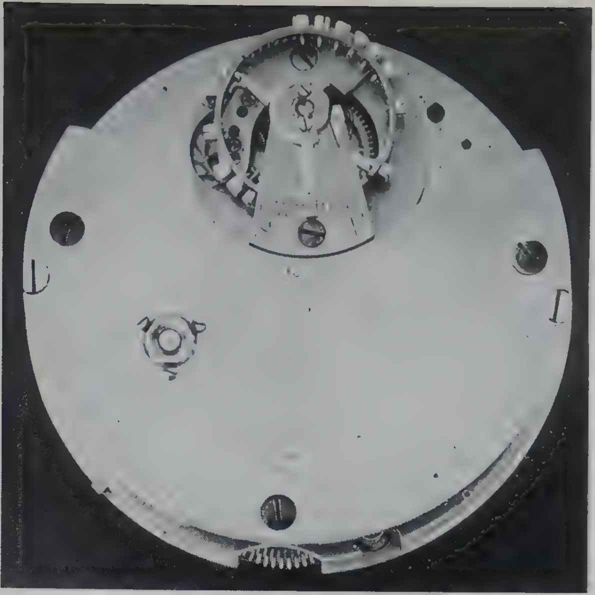
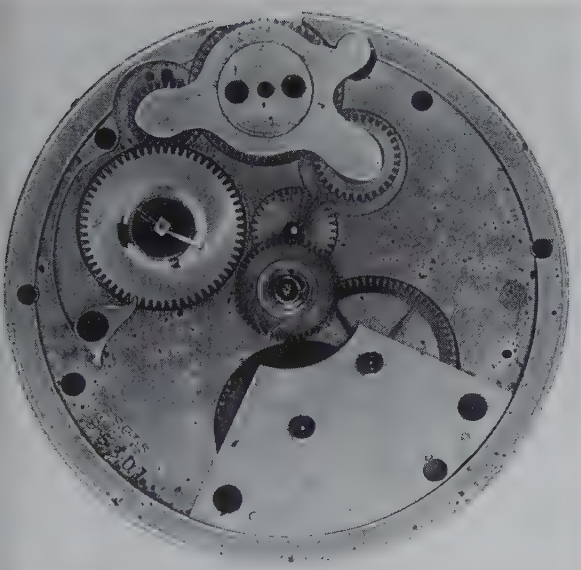

e

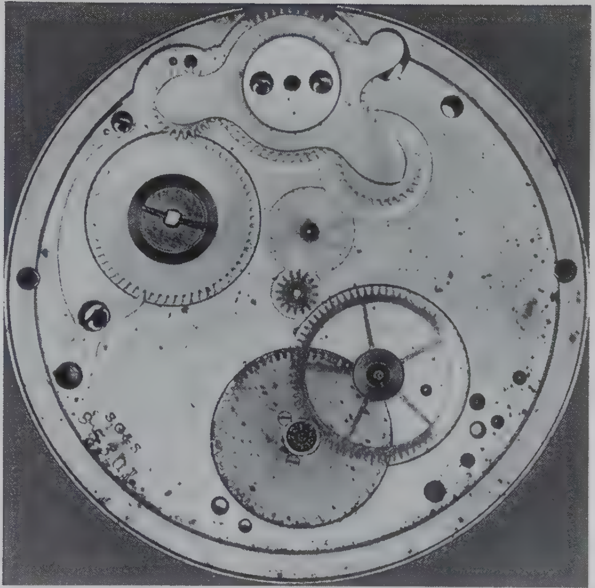
Plate 153

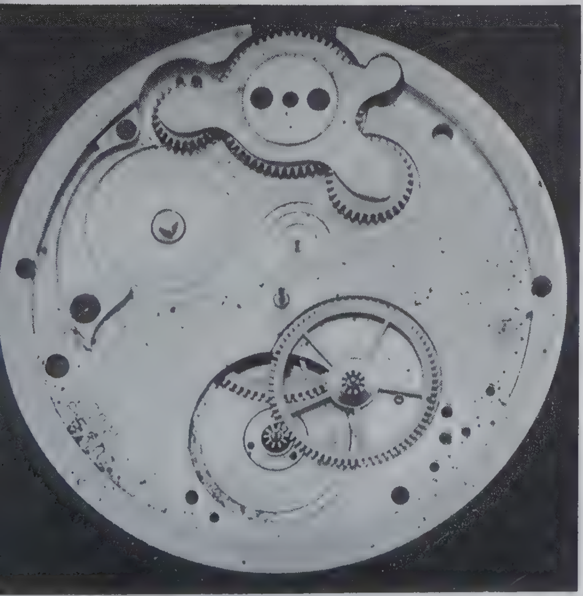
- **a.** Cat. no. 185.
- **b.** Cat. no. 185.
- **c.** Cat. no. 185.
- **d.** Cat. no. 185.
- **e.** Cat. no. 185.
- **f.** Cat. no. 185.


a


b


c


d


e

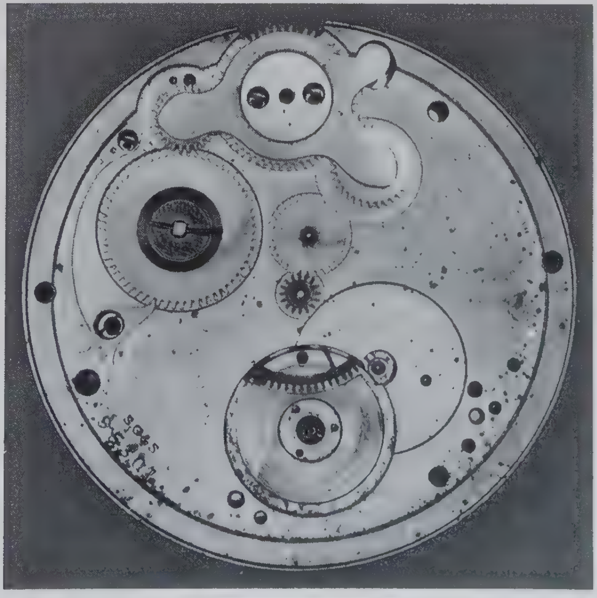
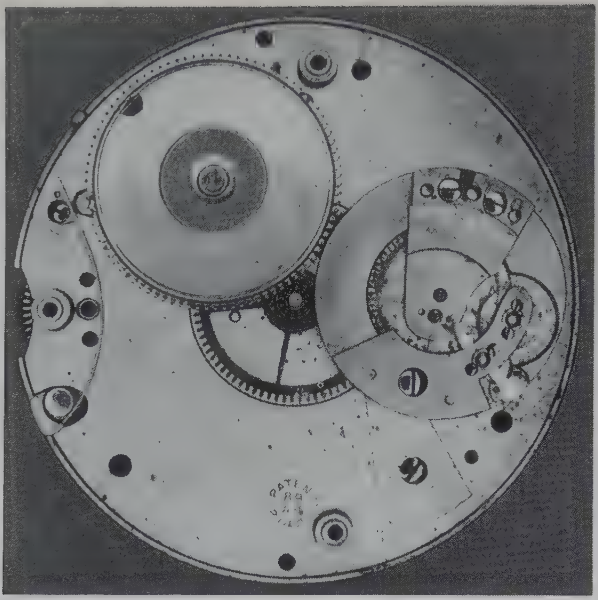
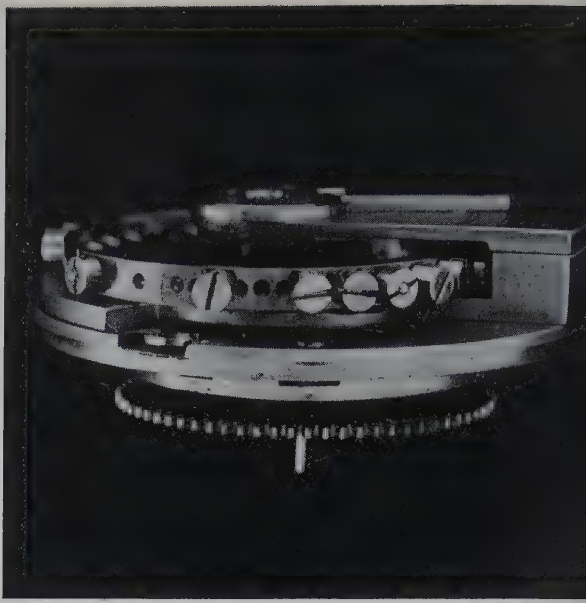
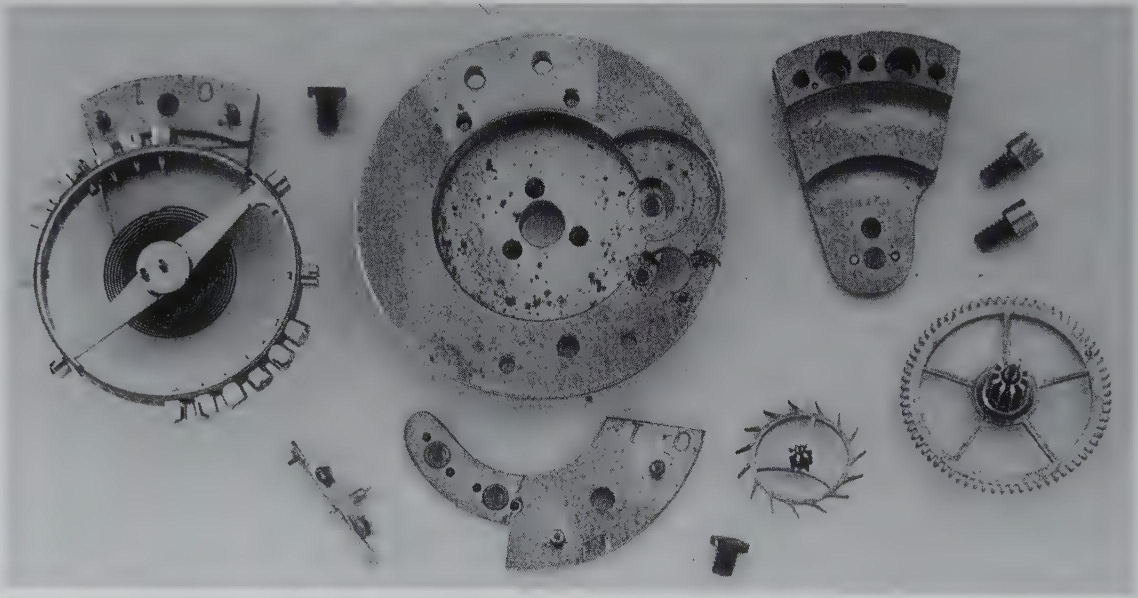

f

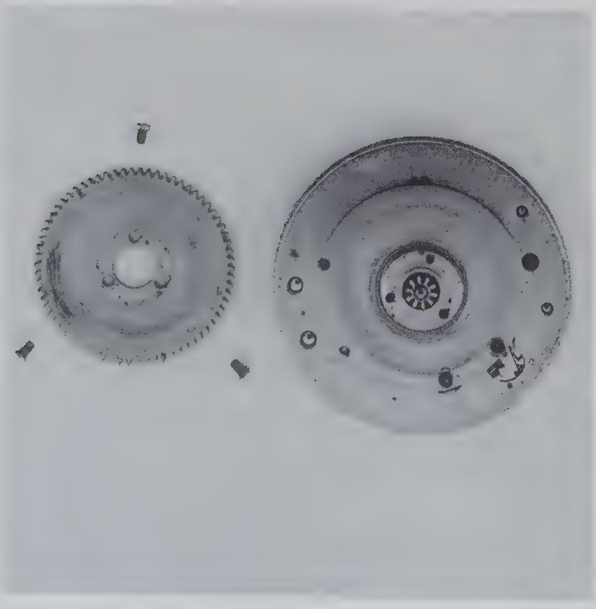
Plate 154

a. Cat. no. 185.
b. Cat. no. 185.
c. Cat. no. 185.
d. Cat. no. 185.
e. Cat. no. 185.


a


b


c


d

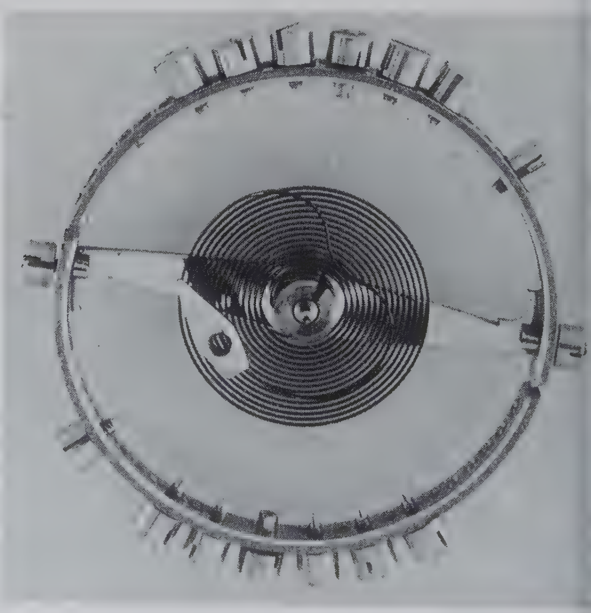
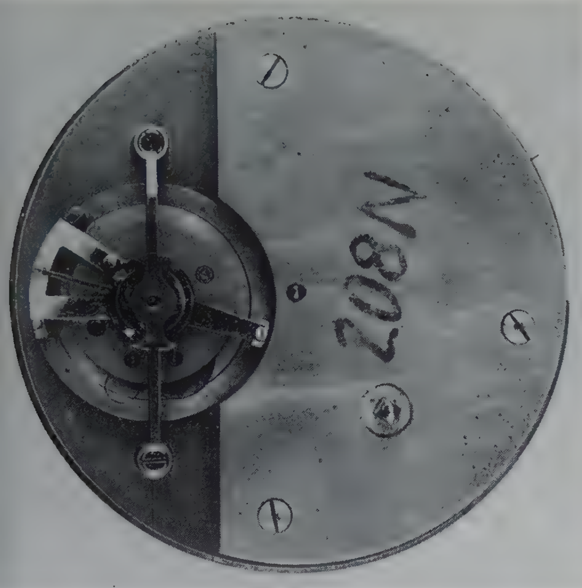
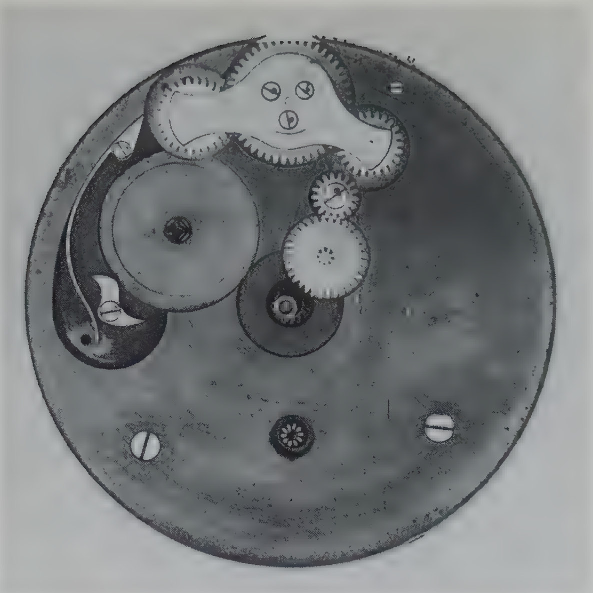

e

Plate 155

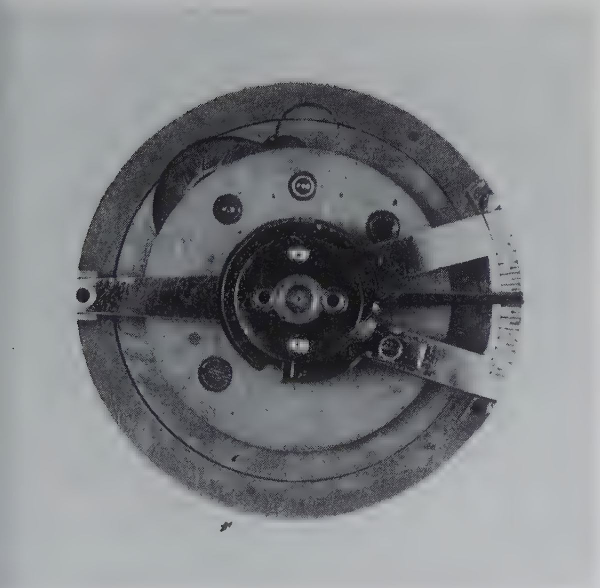
a. Cat. no. 186.
b. Cat. no. 186.
c. Cat. no. 186.
d. Cat. no. 186.
e. Cat. no. 187.
f. Cat. no. 187.



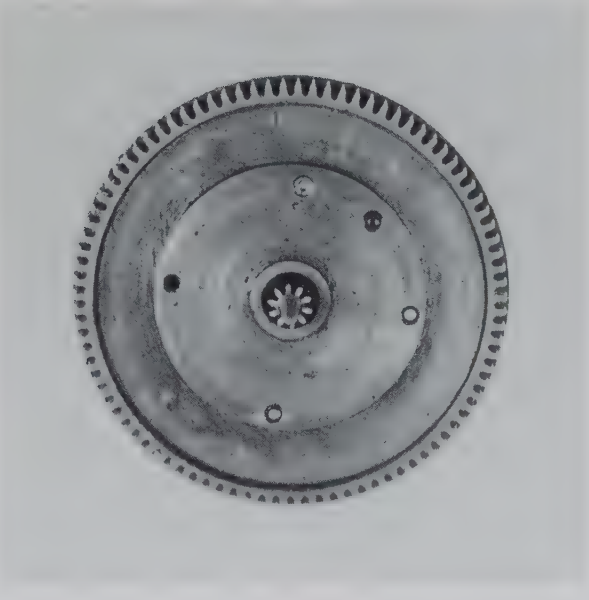
a



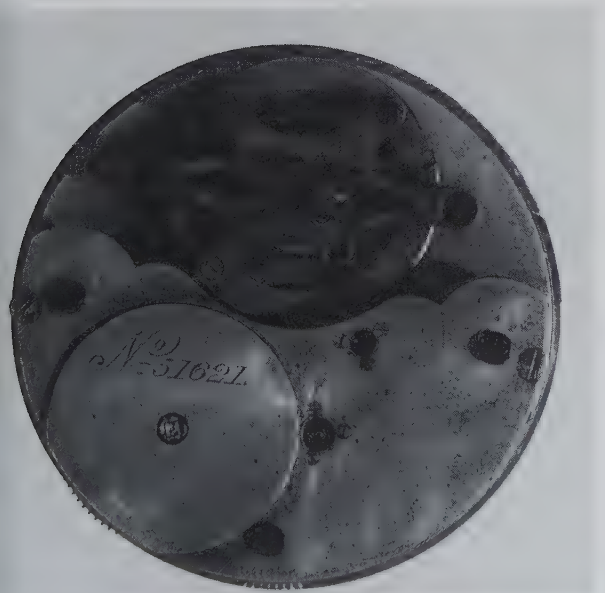
b



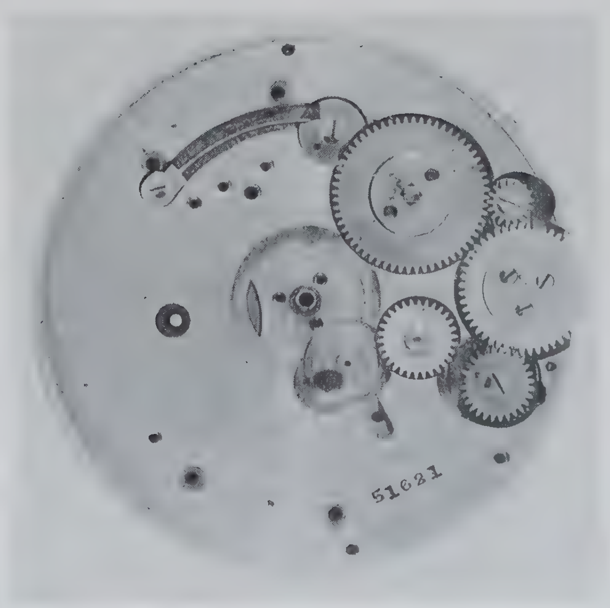
c



d



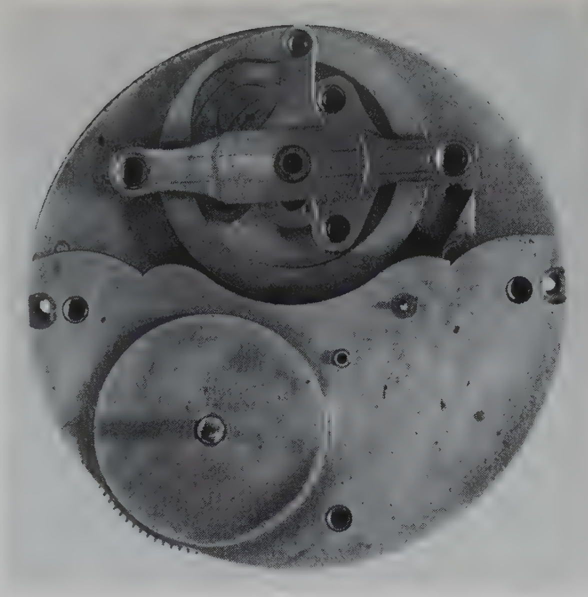
e



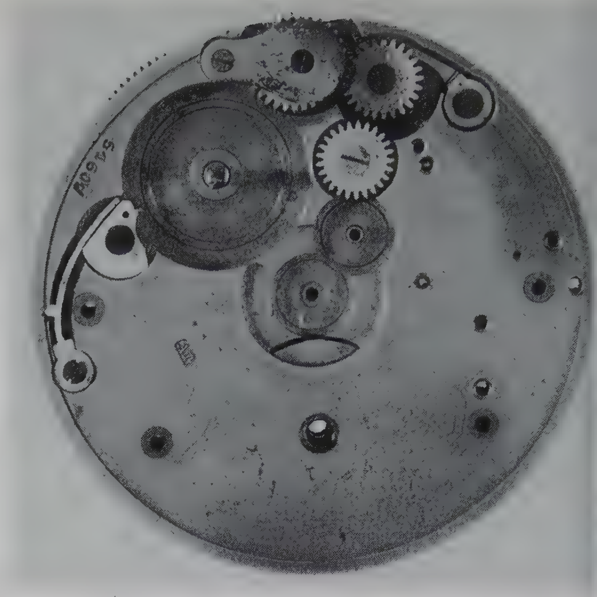
f

Plate 156

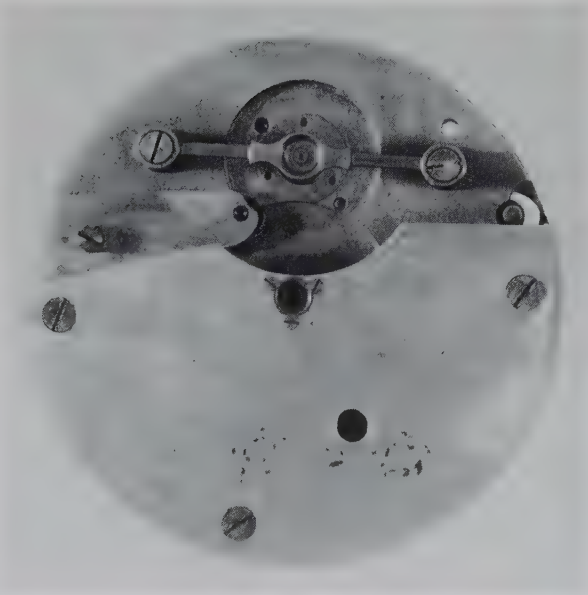
- **a.** Cat. no. 188.
- **b.** Cat. no. 188.
- **c.** Cat. no. 189.
- **d.** Cat. no. 189.
- **e.** Cat. no. 190.
- **f.** Cat. no. 190.



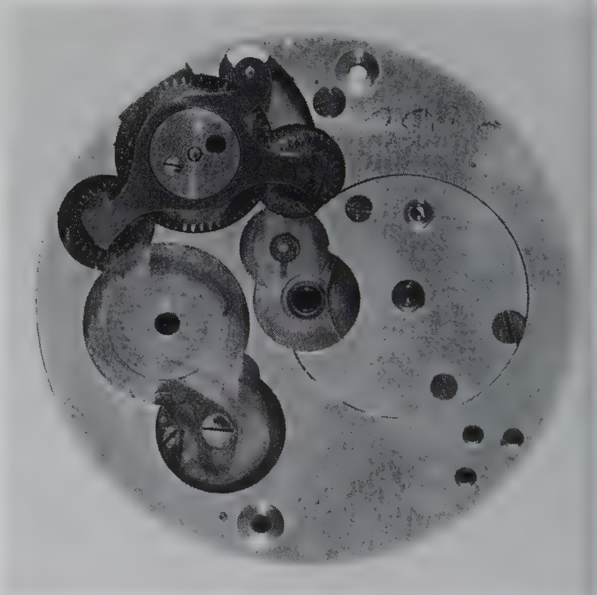
a



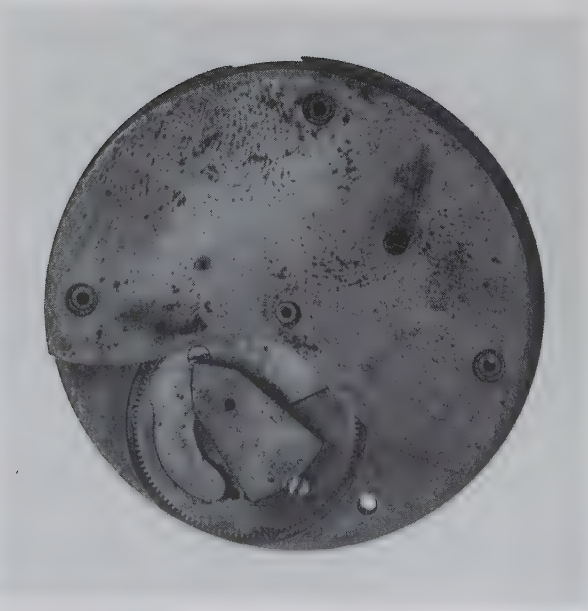
b



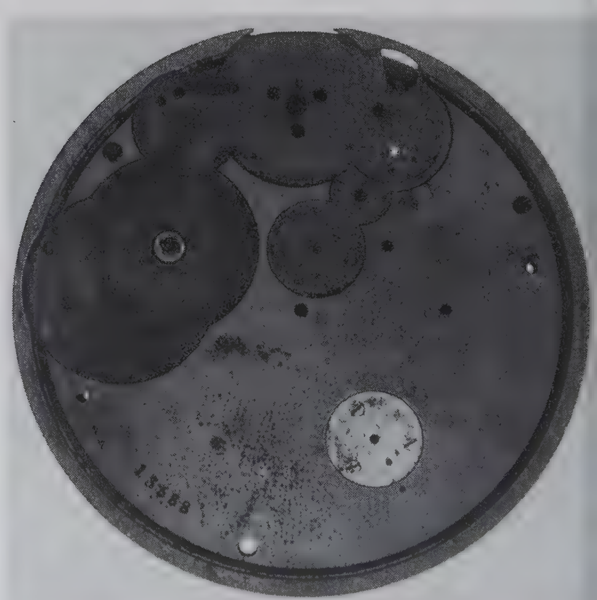
c



d



e



f

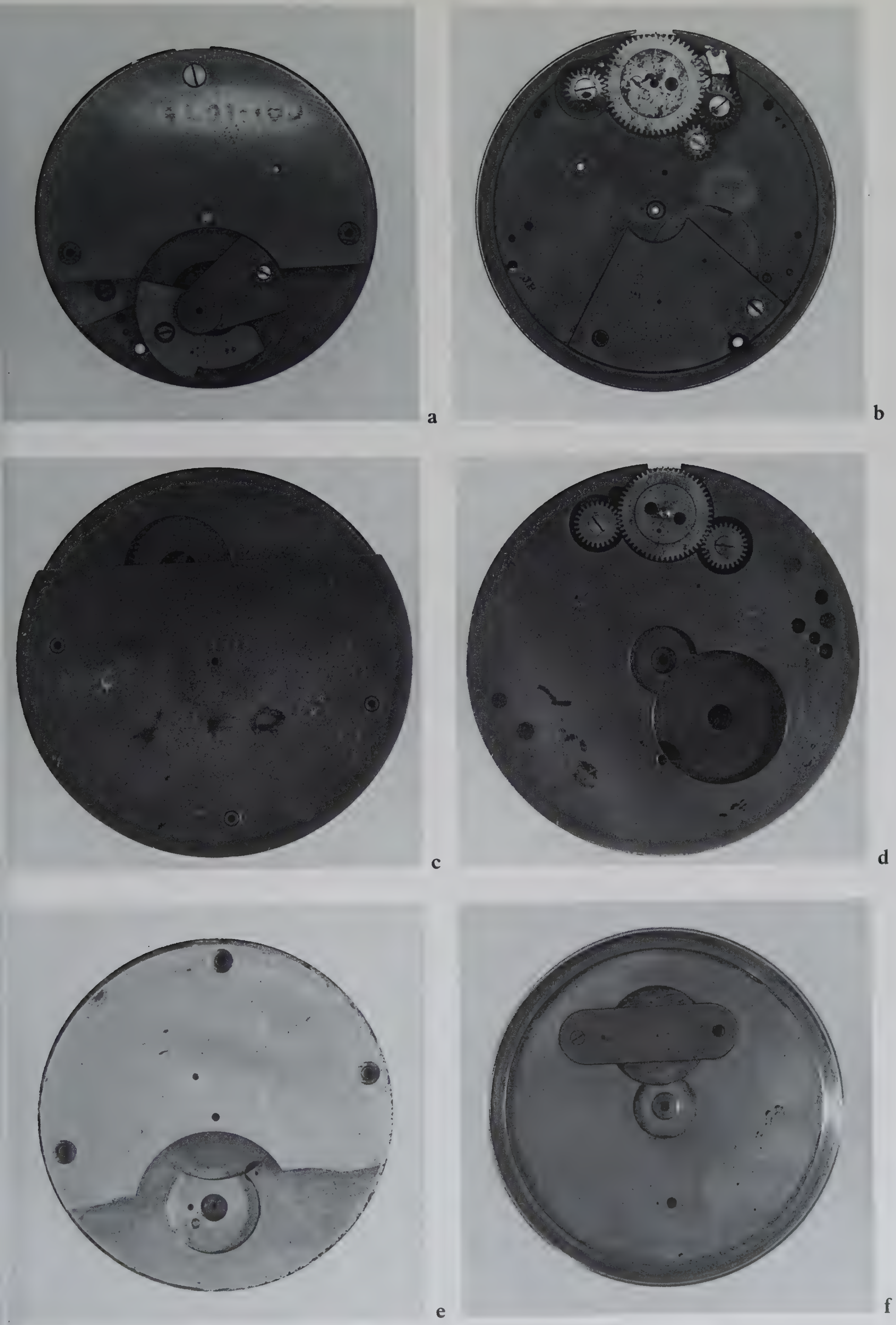


Plate 157

a. Cat. no. 191.
b. Cat. no. 191.
c. Cat. no. 192.
d. Cat. no. 192.
e. Cat. no. 193.
f. Cat. no. 193.

Plate 158

a. Cat. no. 194.
b. Cat. no. 196.
c. Cat. no. 197.
d. Cat. no. 198.
e. Cat. no. 203, the balance. One of its weights (on the left) has been replaced by cat. no. 282.
Cat. no. 283 is on the right.

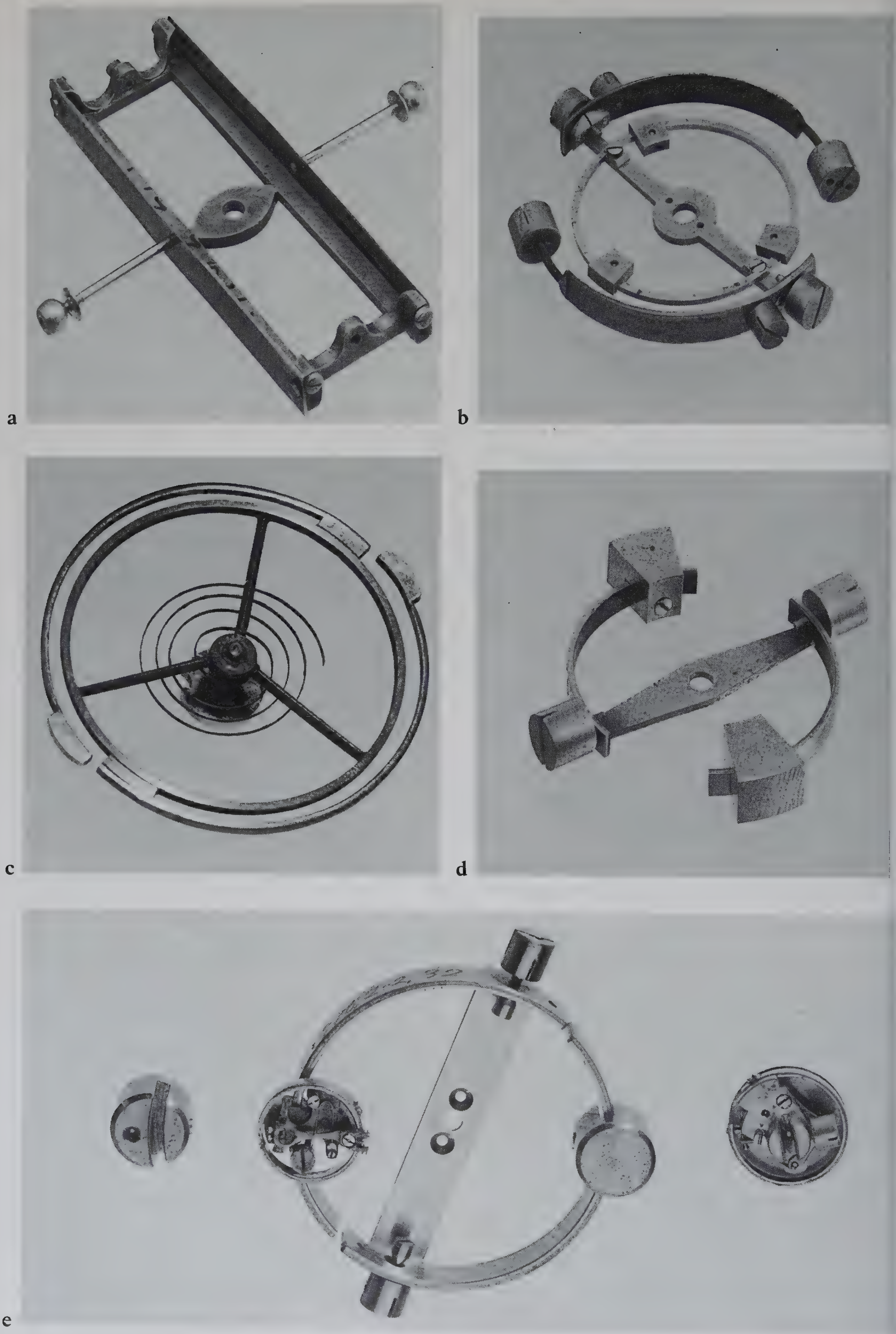
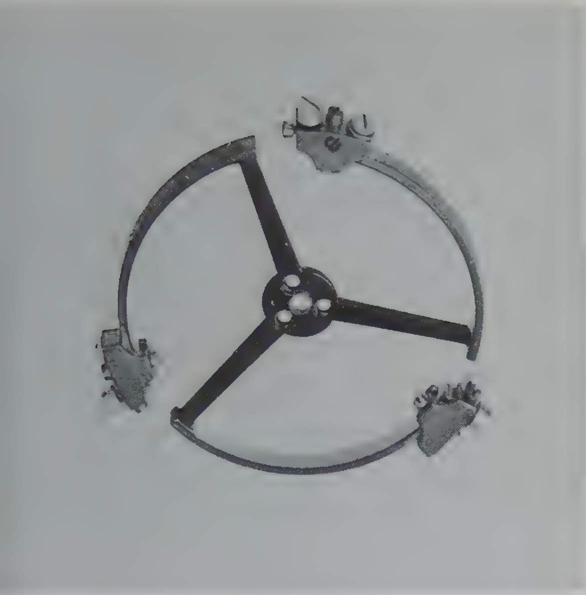
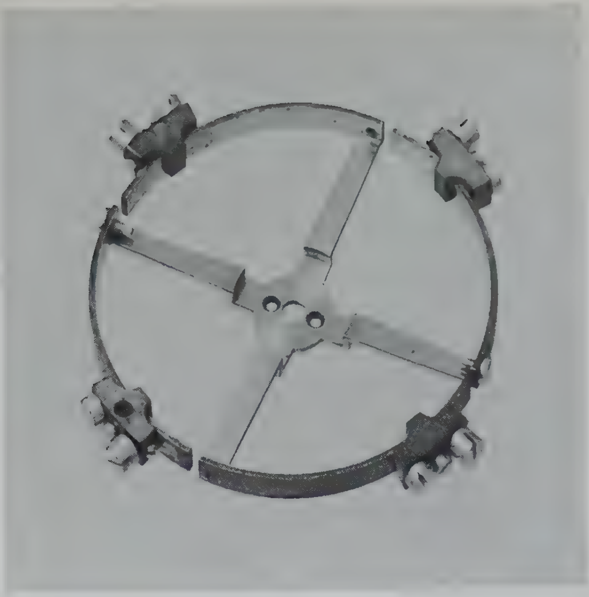
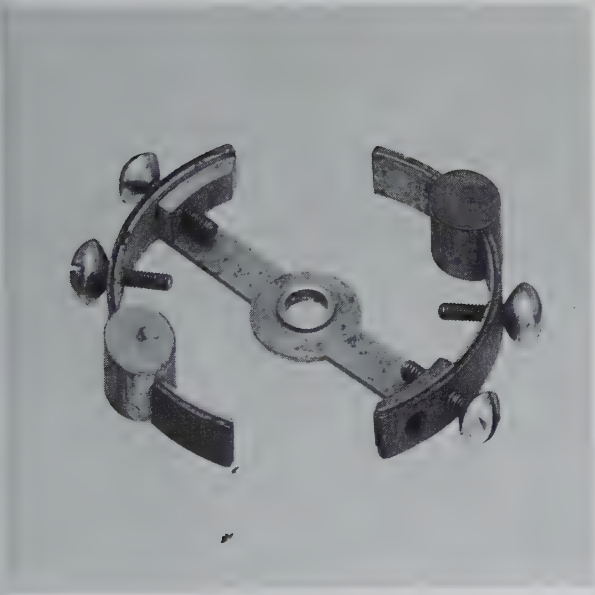


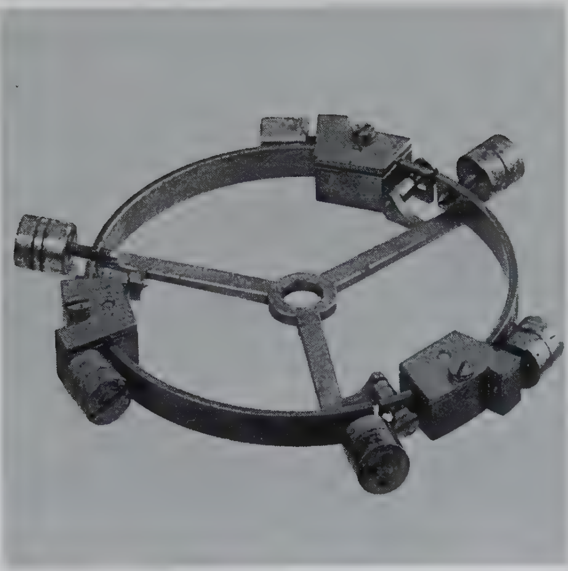
Plate 159

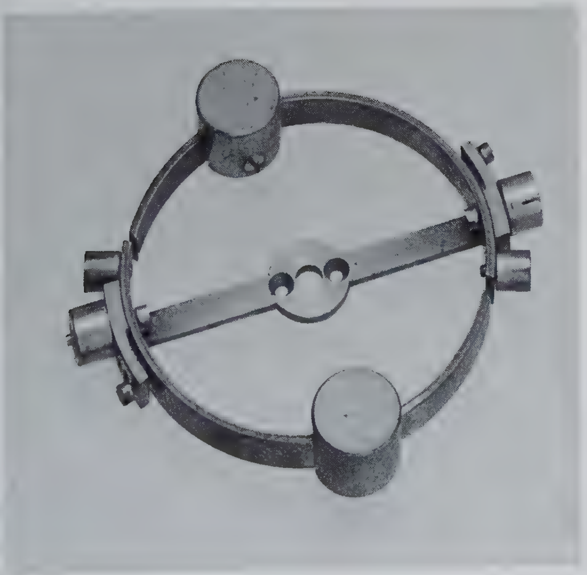
a. Cat. no. 214.
b. Cat. no. 215.
c. Cat. no. 216.
d. Cat. no. 218.
e. Cat. no. 219.
f. Cat. no. 220.


a


b


c


d


e

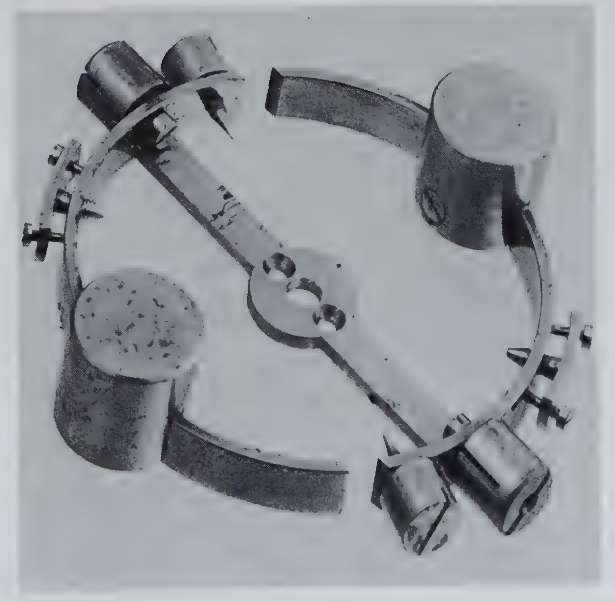

f

Plate 160

a. Cat. no. 221.
b. Cat. nos. 222, 223.
c. Cat. no. 224.
d. Cat. no. 225.
e. Cat. no. 226.
f. Cat. no. 227.

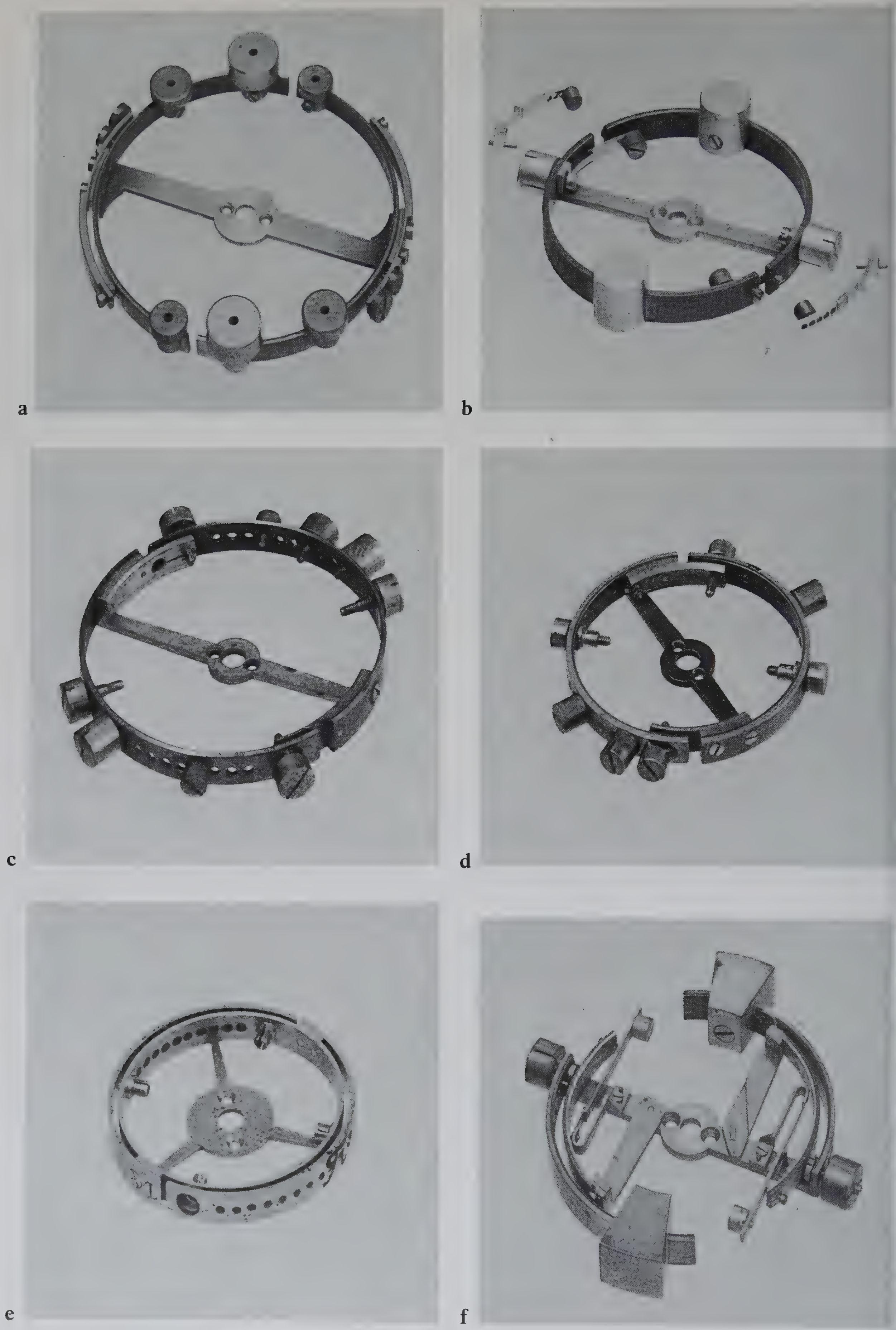


Plate 161

- **a.** Cat. no. 228.
- **b.** Cat. no. 229.
- **c.** Cat. no. 232.
- **d.** Cat. no. 233.
- **e.** Cat. no. 236.
- **f.** Cat. no. 237.

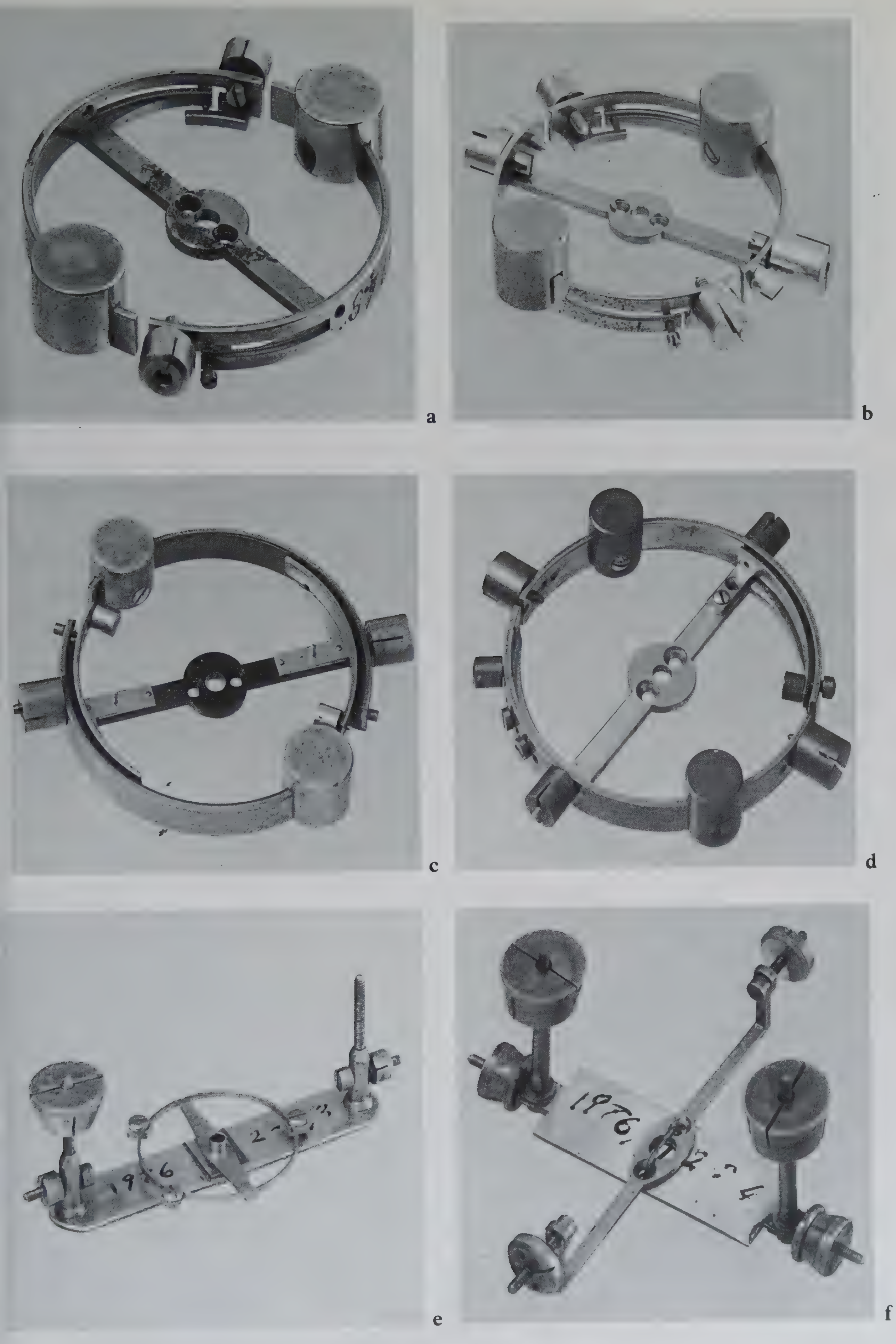
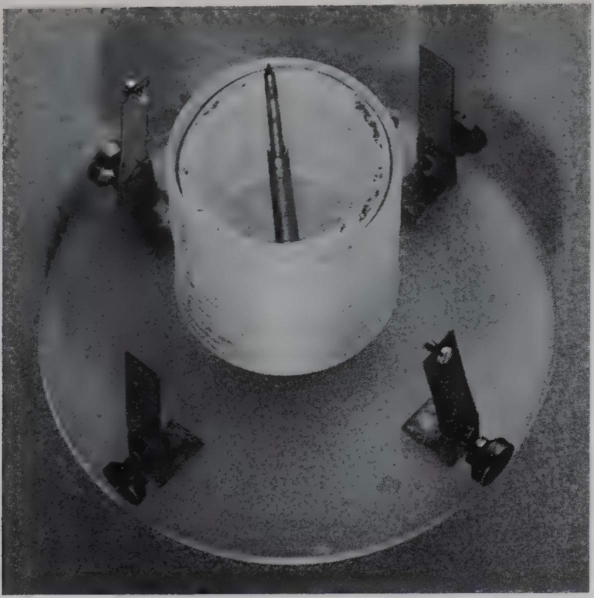
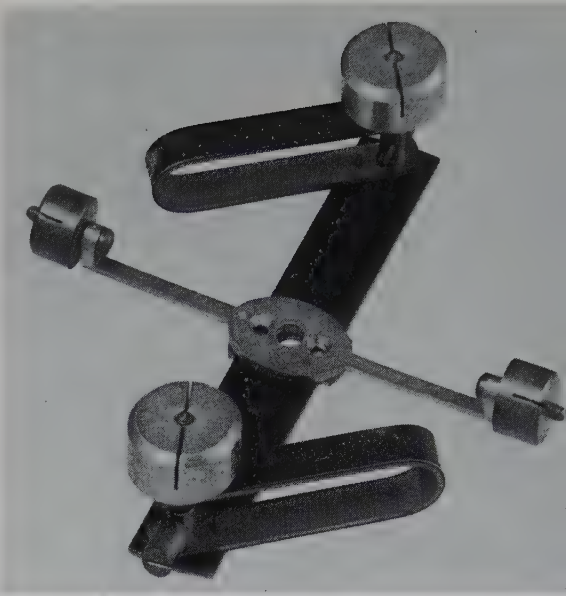
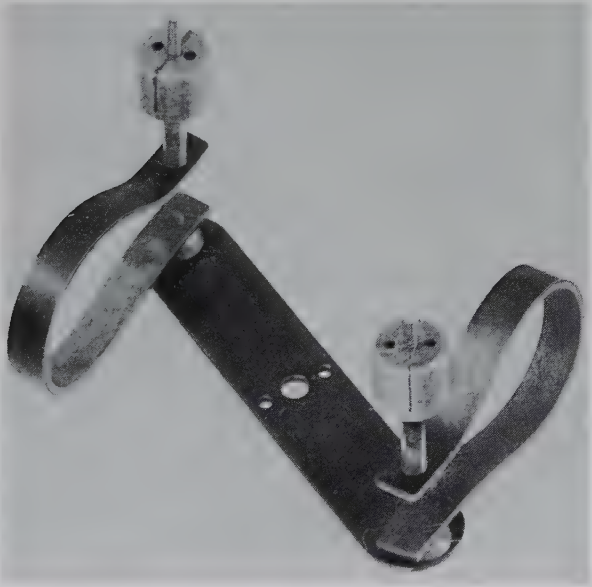

a
b
c
d
e
f
1976

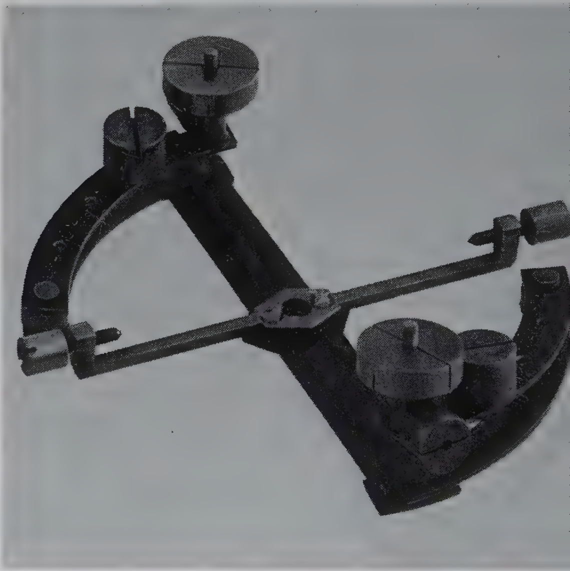
Plate 162

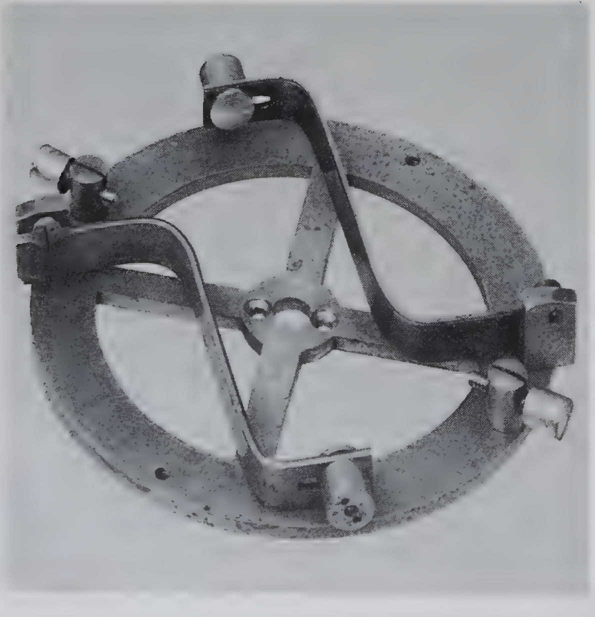
a. Cat. no. 238.
b. Cat. no. 239.
c. Cat. no. 240.
d. Cat. no. 241.
e. Cat. no. 242.
f. Cat. no. 243.


a


b


c


d


e

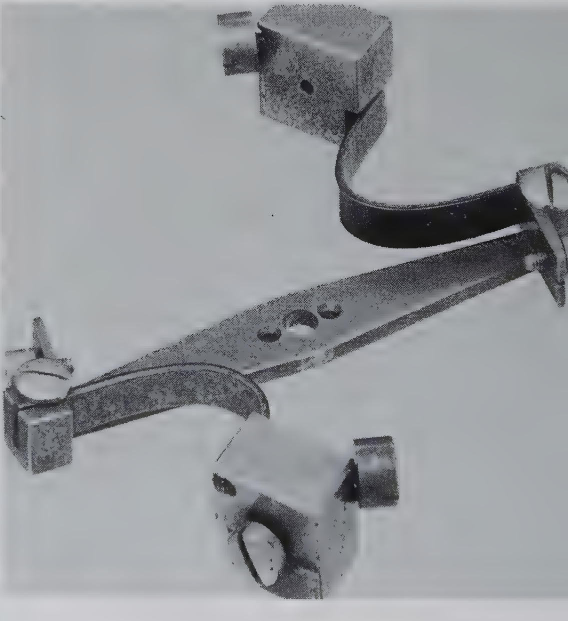
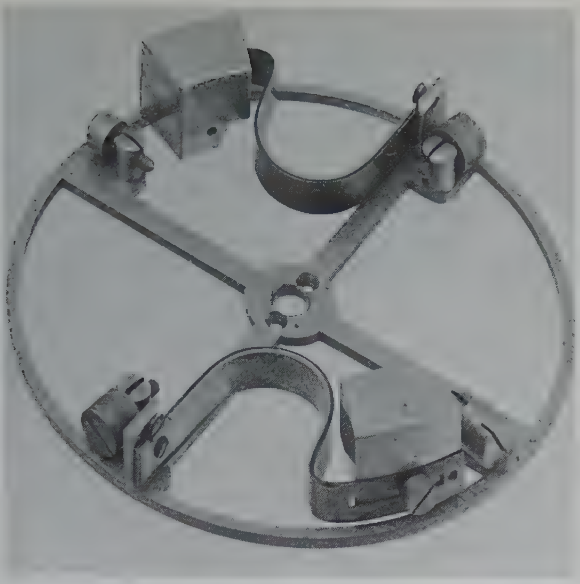
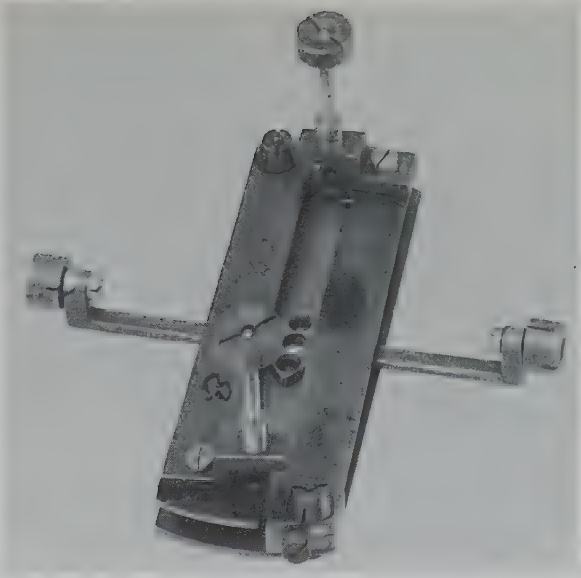

f

Plate 163

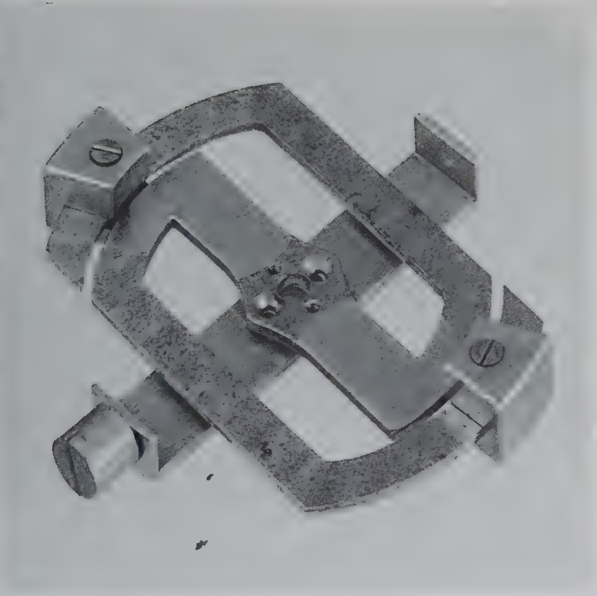
a. Cat. no. 244.
b. Cat. no. 245.
c. Cat. no. 246.
d. Cat. no. 247.
e. Cat. no. 248.
f. Cat. no. 249.



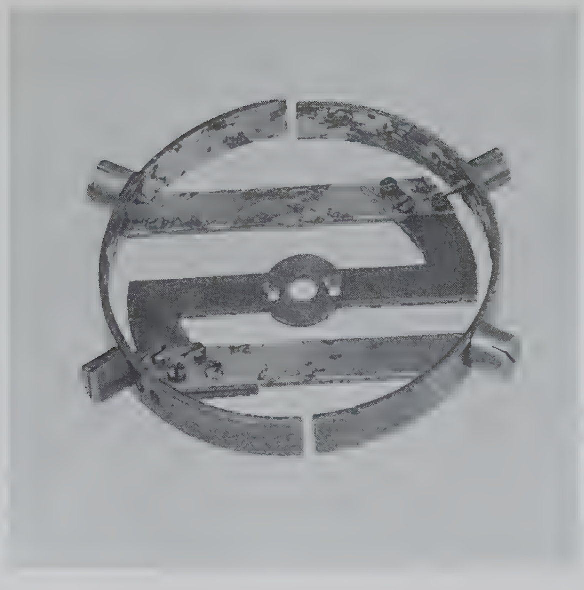
a



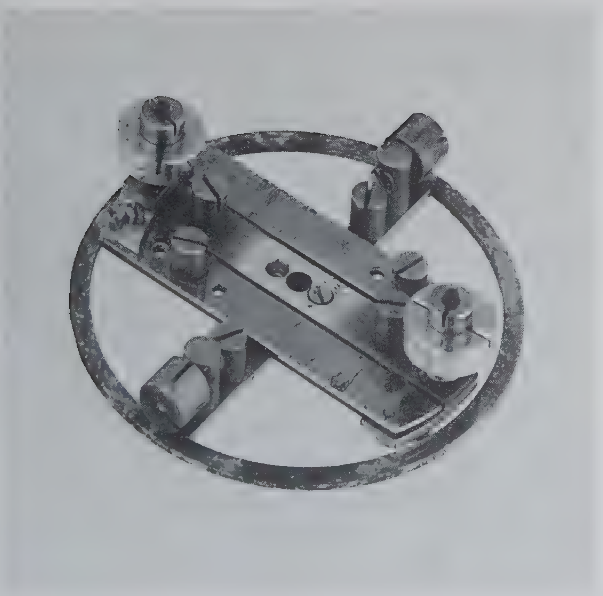
b



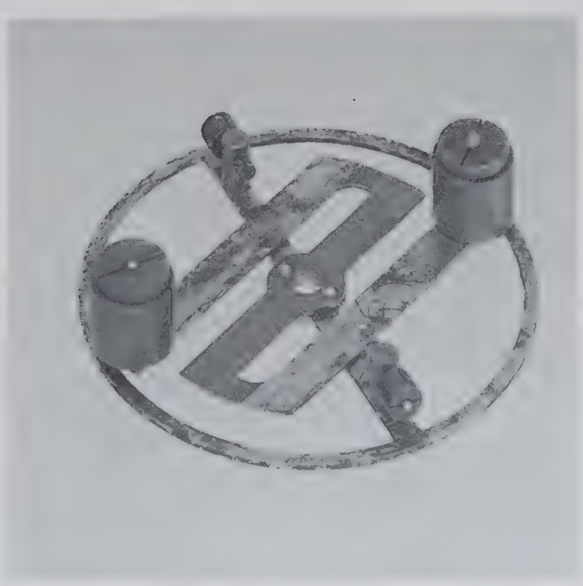
c



d



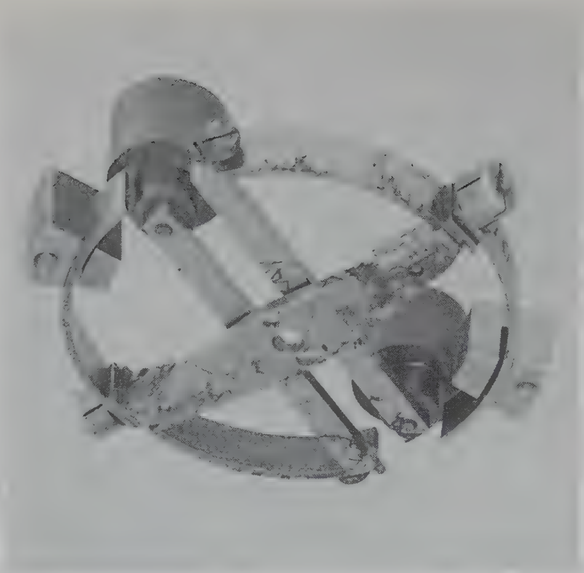
e



f

Plate 164

a. Cat. no. 251.
b. Cat. no. 251.
c. Cat. no. 252.
d. Cat. no. 253.
e. Cat. no. 254.
f. Cat. no. 255.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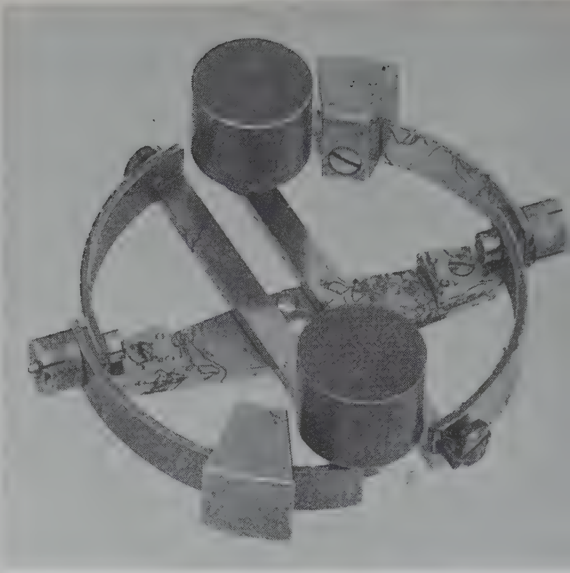
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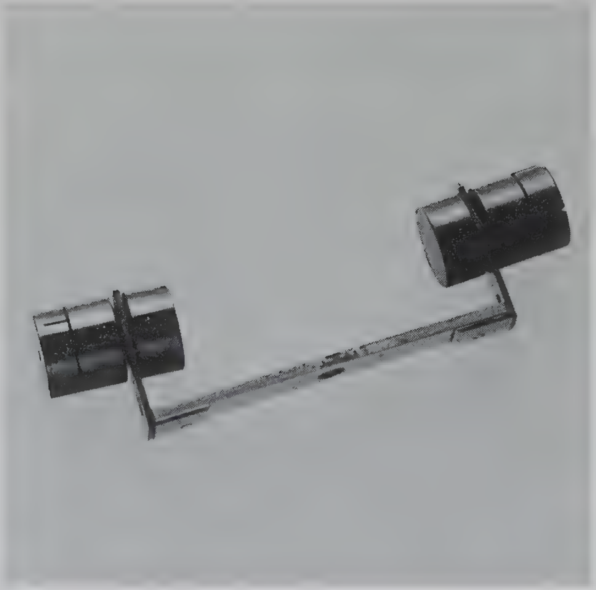
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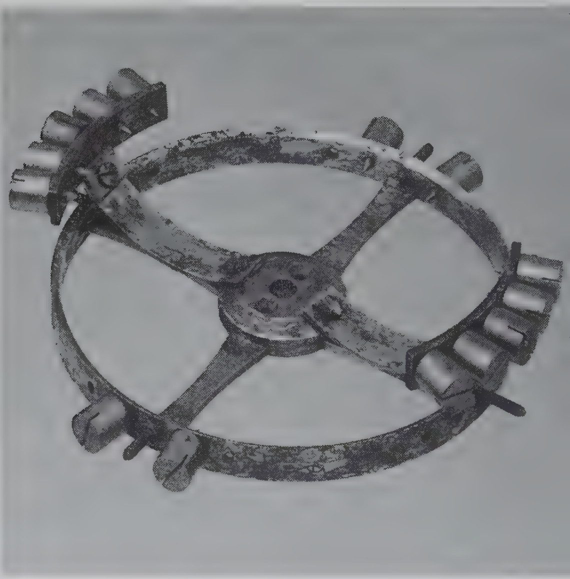
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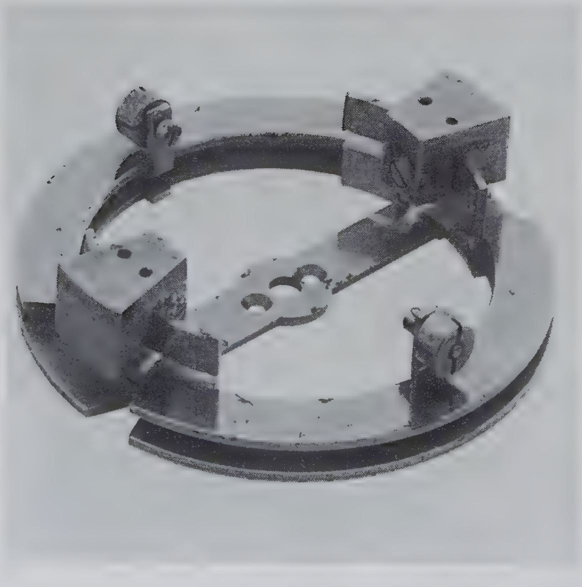

e

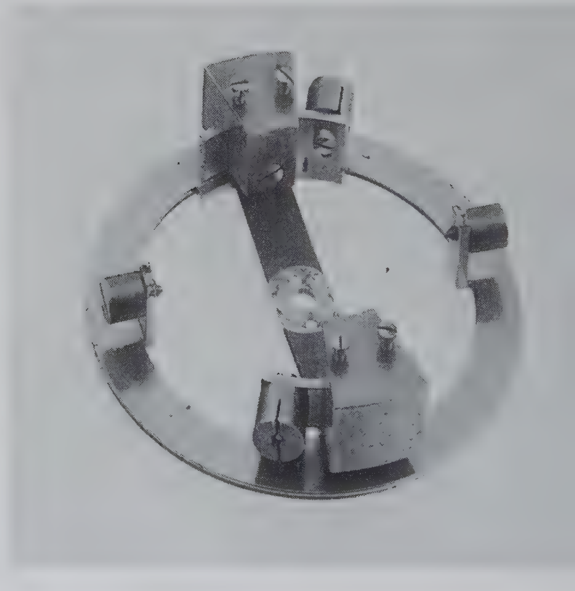
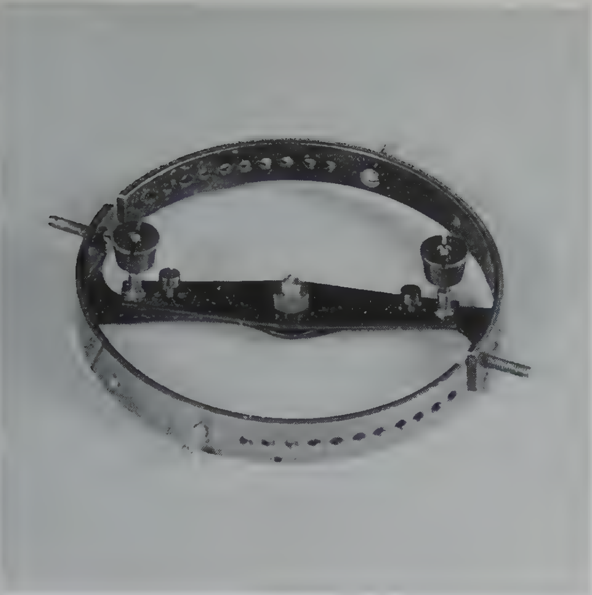

f

Plate 165

a. Cat. no. 259.
b. Cat. no. 260.
c. Cat. no. 261.
d. Cat. no. 266.
e. Cat. no. 267.
f. Cat. no. 268.



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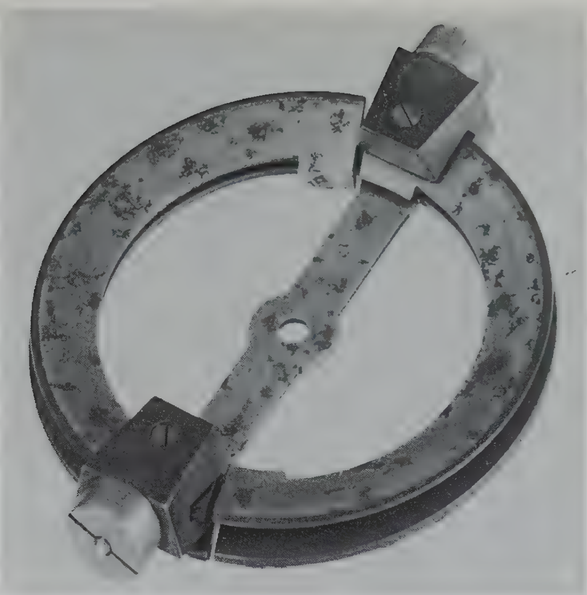
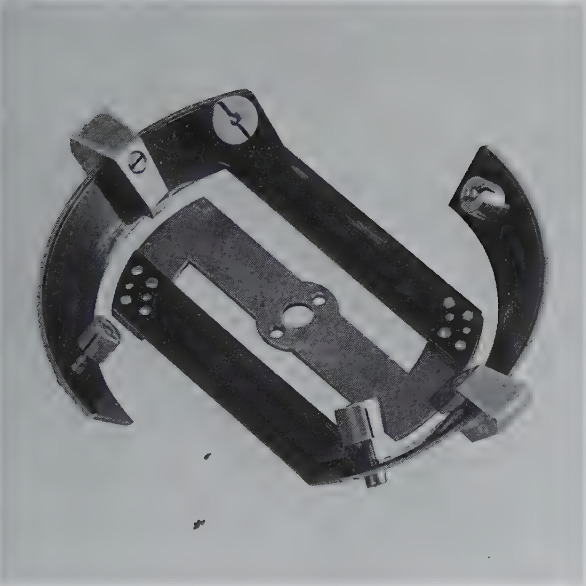
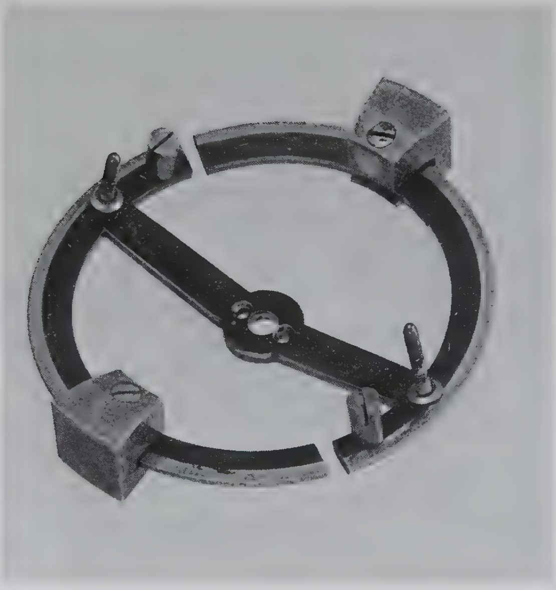


b





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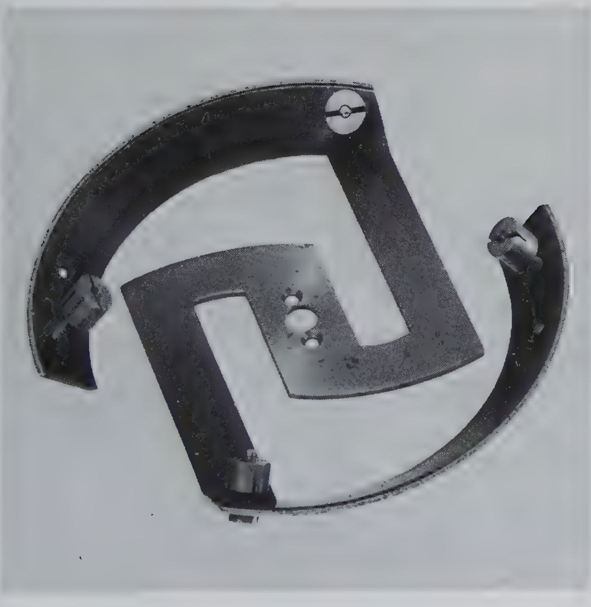

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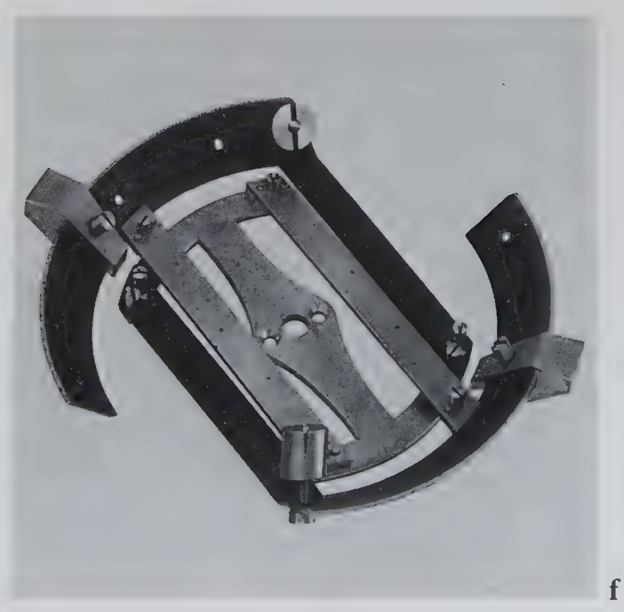
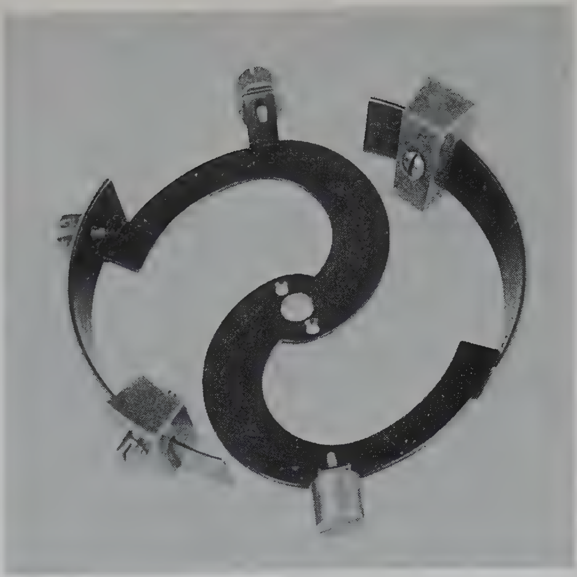
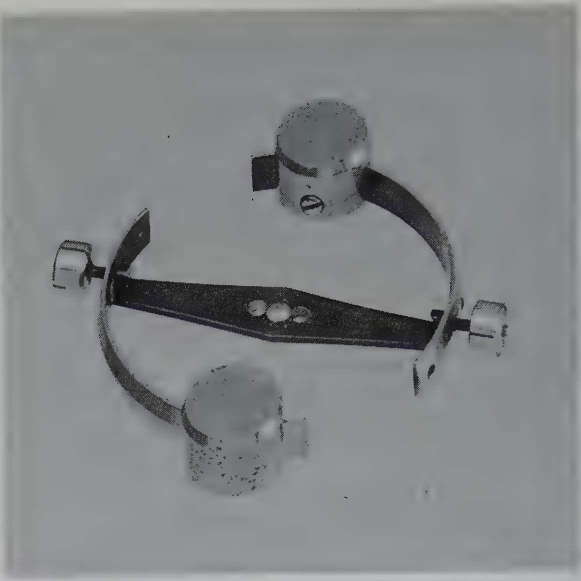


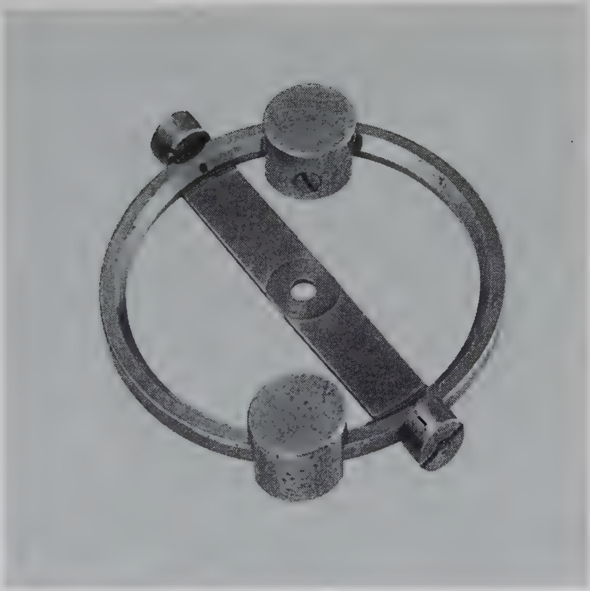
f

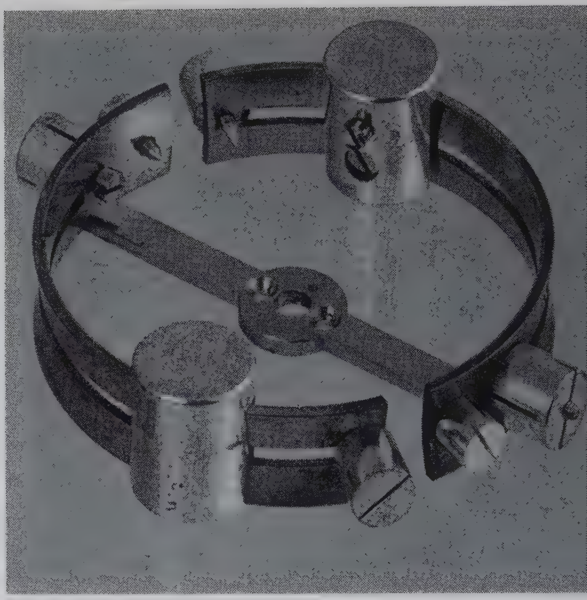
Plate 166

a. Cat. no. 269.
b. Cat. no. 270.
c. Cat. no. 271.
d. Cat. no. 272.
e. Cat. no. 273.
f. Cat. no. 274.


a


b


c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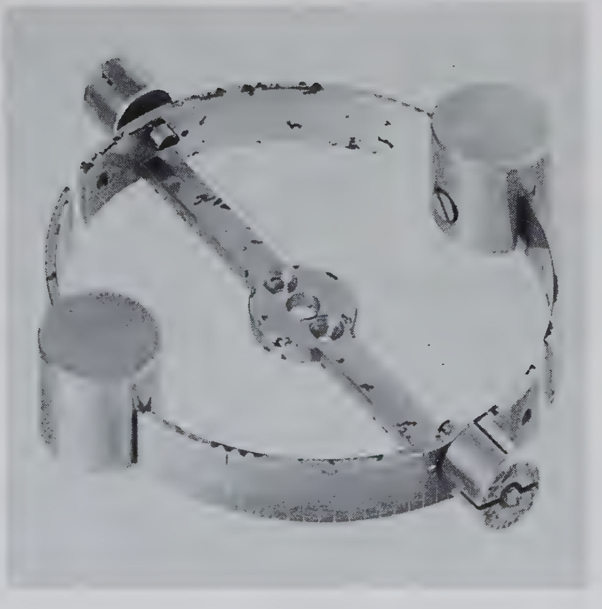
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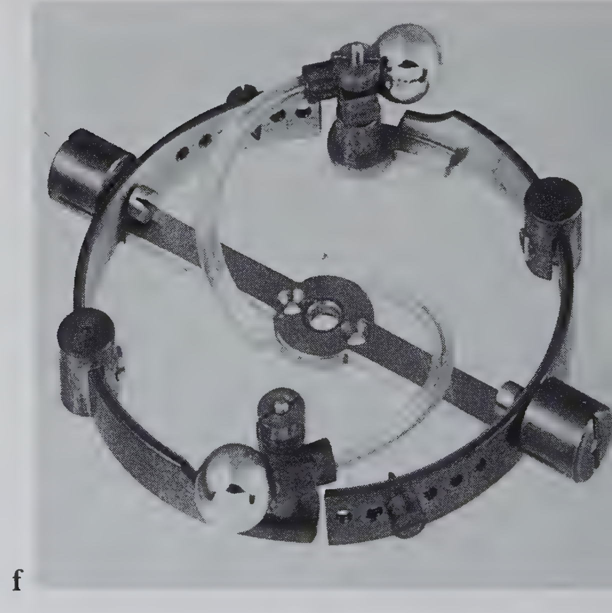
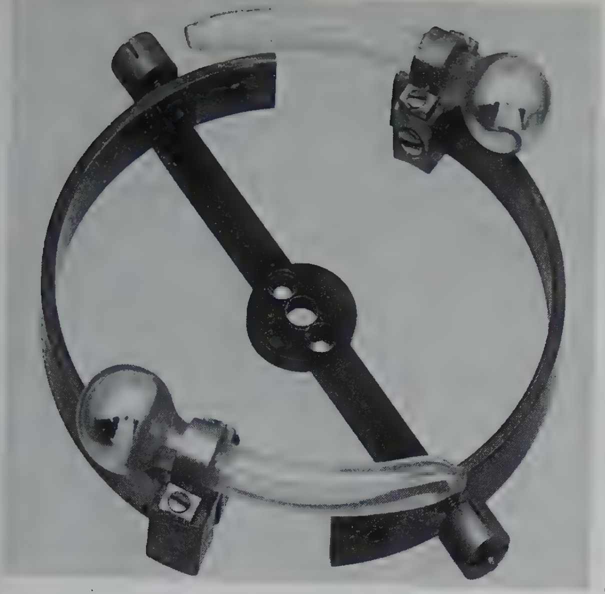
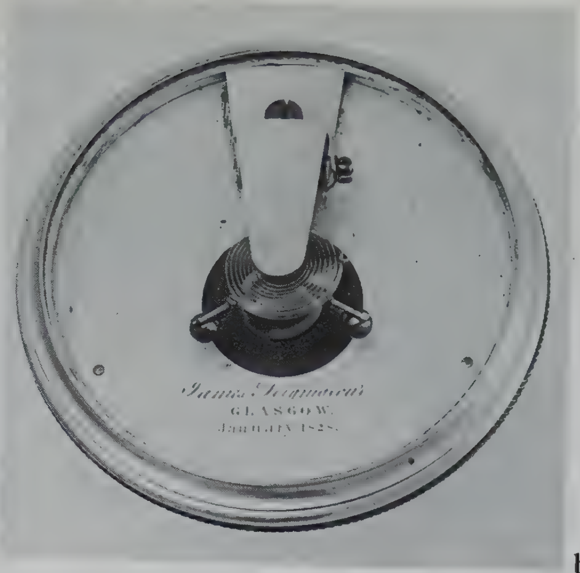

f

Plate 167

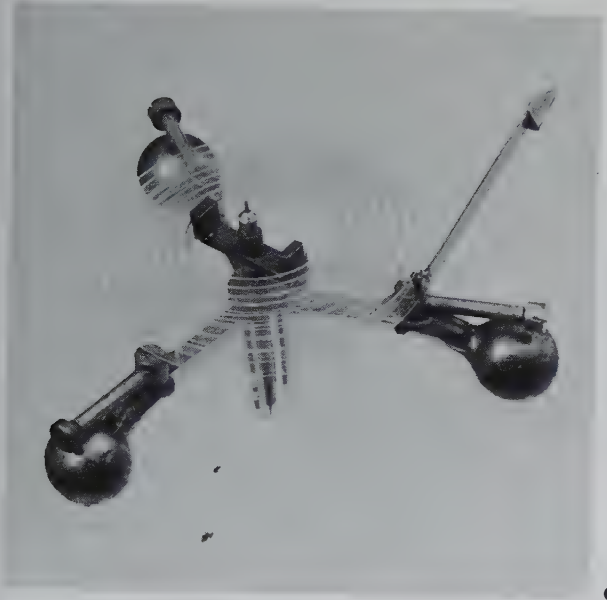
a. Cat. no. 275.
b. Cat. no. 276.
c. Cat. no. 276.
d. Cat. no. 282.
e. Cat. no. 282.



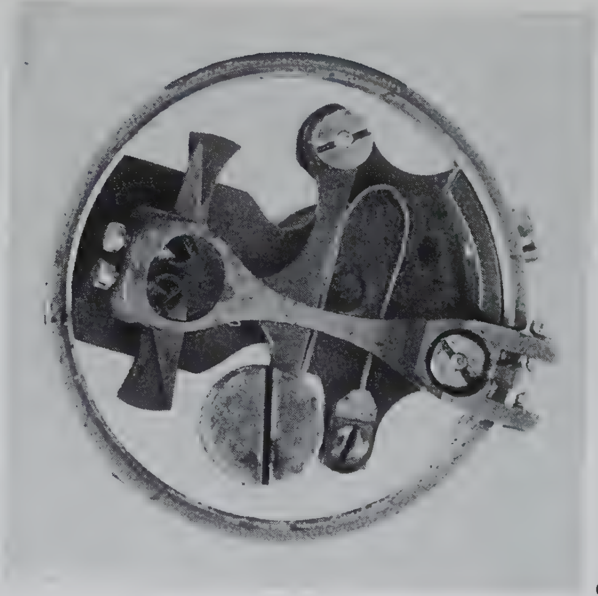
a


James Ferguson's
GLASGOW.
January 1828.

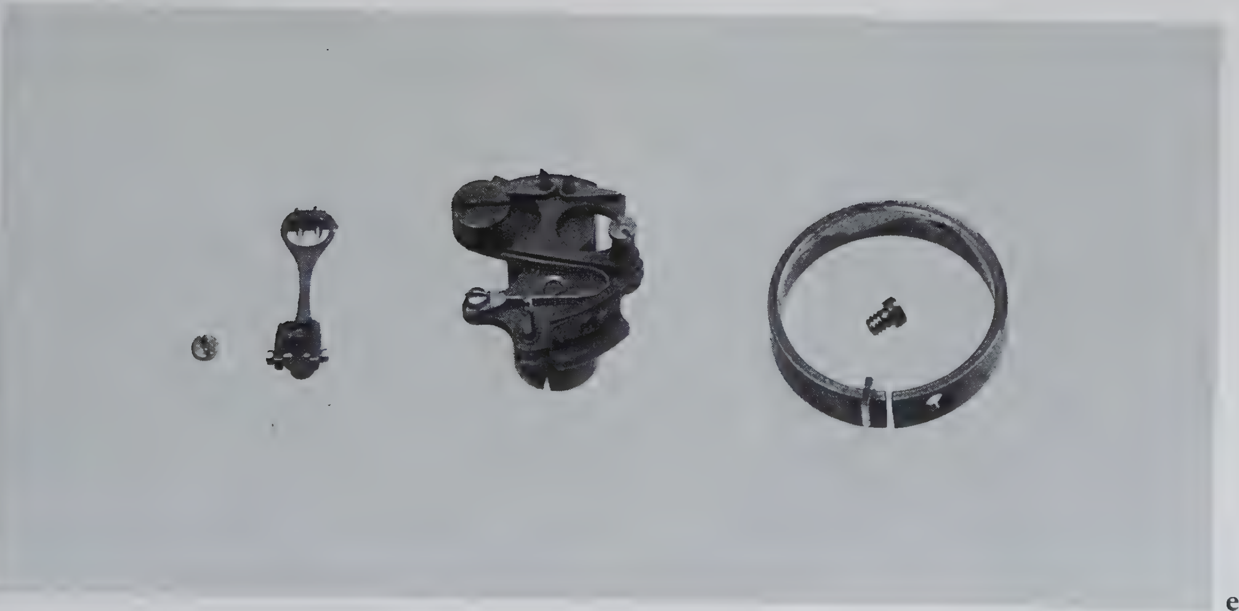
b



c



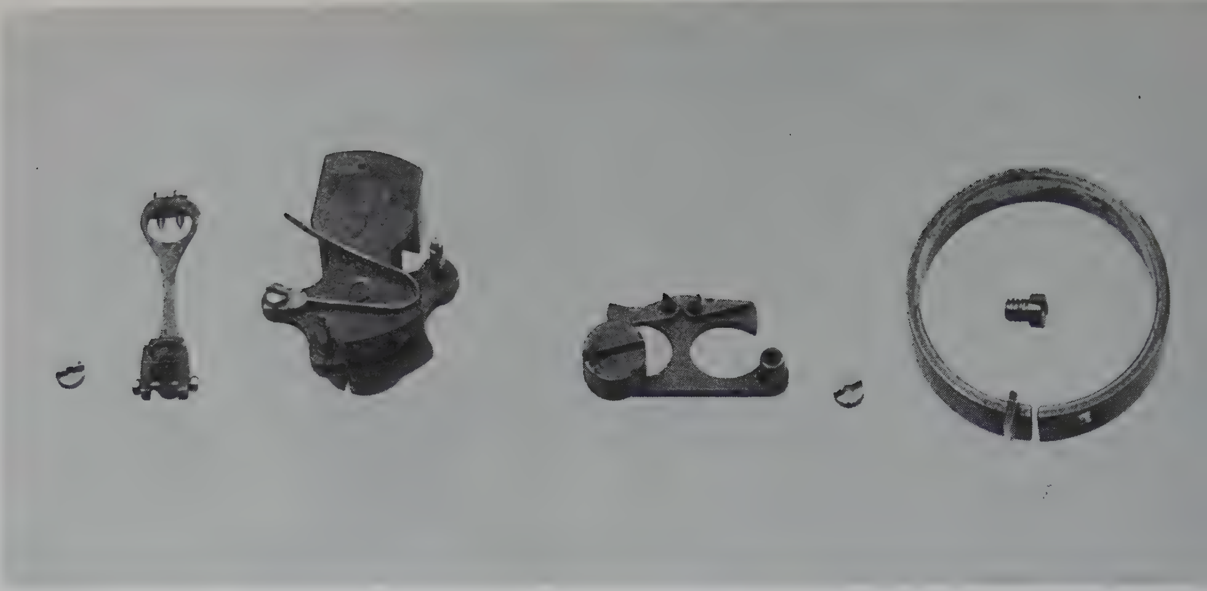
d



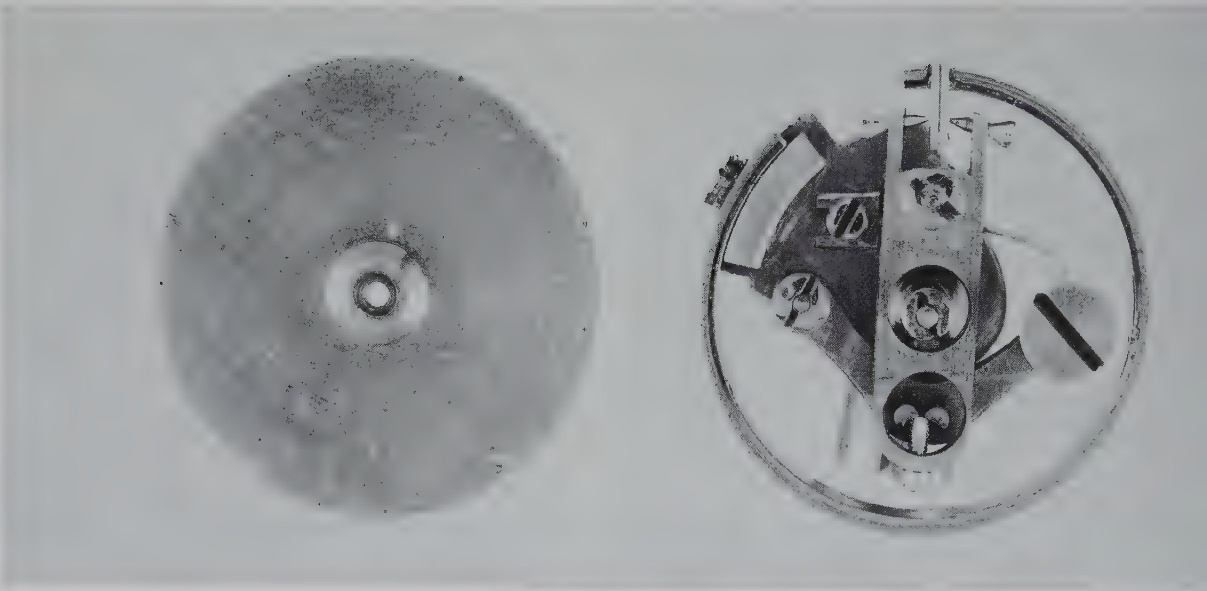
e

Plate 168

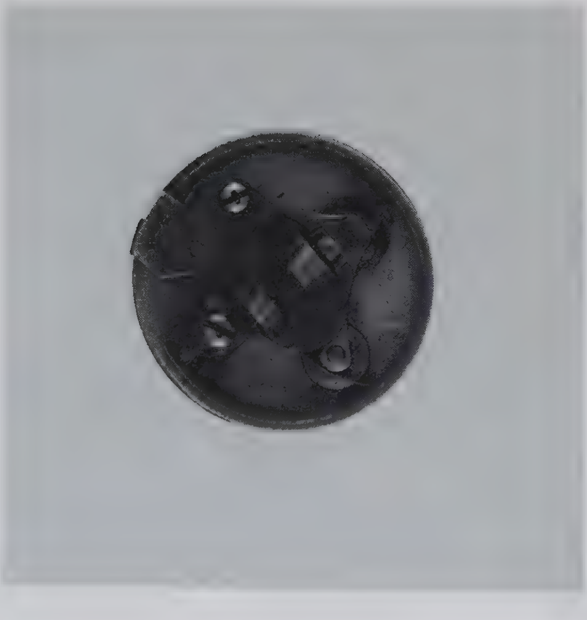
- **a.** Cat. no. 282.
- **b.** Cat. no. 283.
- **c.** Cat. no. 284.
- **d.** Cat. no. 284.



a



b



c

d

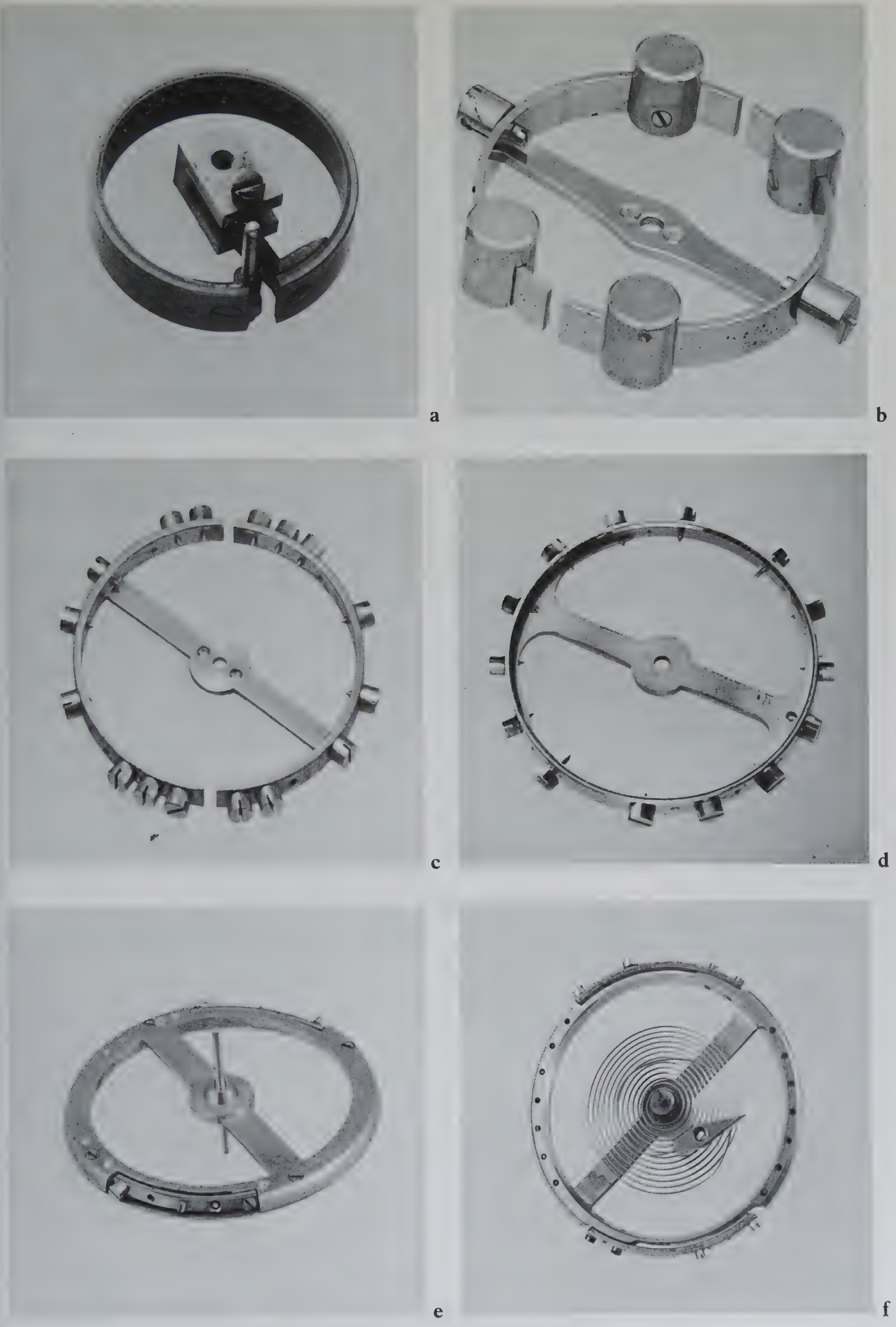
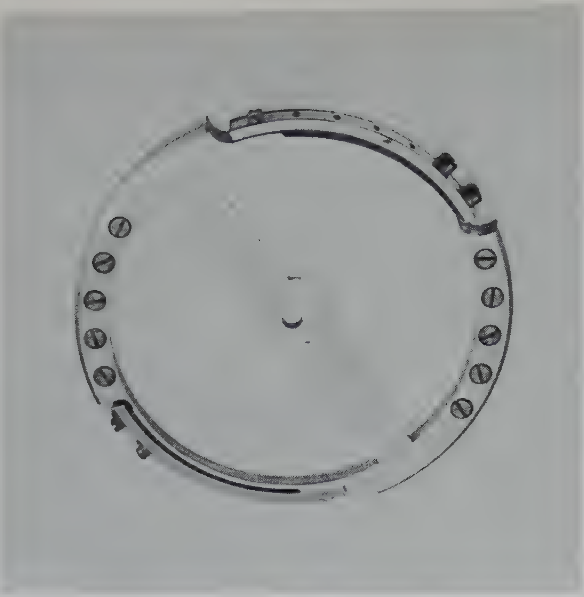


Plate 169

a. Cat. no. 285.
b. Cat. no. 286.
c. Cat. no. 287.
d. Cat. no. 289.
e. Cat. no. 290.
f. Cat. no. 291.

Plate 170

a. Cat. no. 292.
b. Cat. no. 293.
c. Cat. no. 294.
d. Cat. no. 295.
e. Cat. nos. 296, 297.
f. Cat. nos. 296, 297.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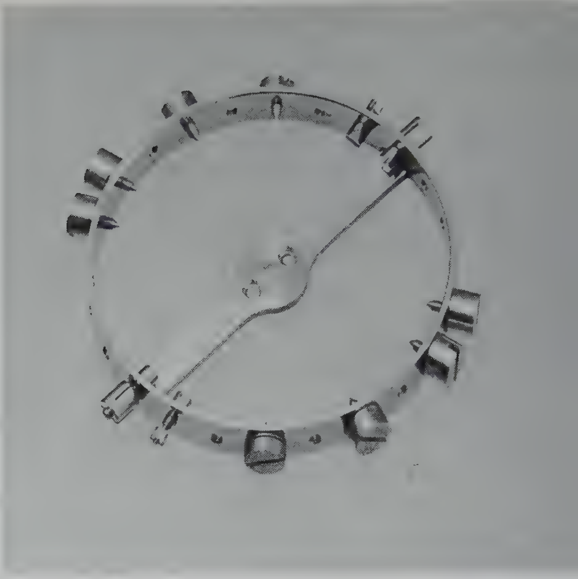
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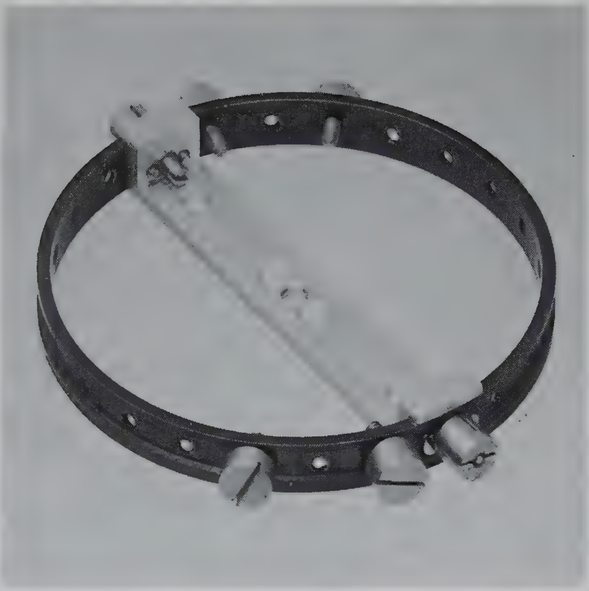
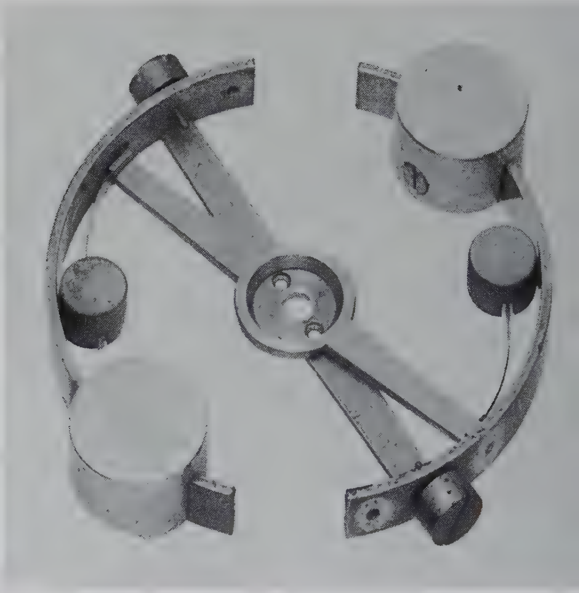
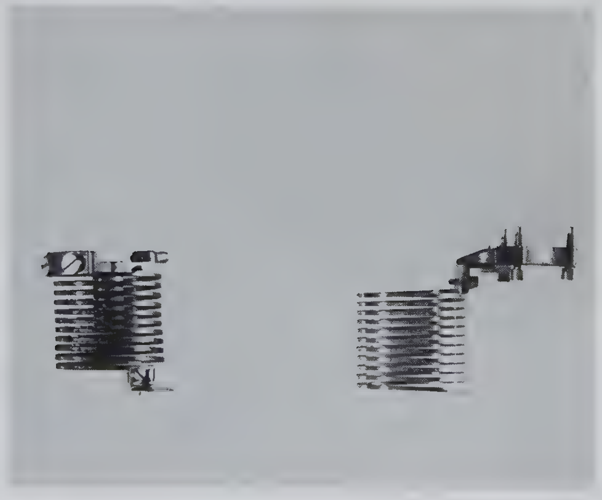
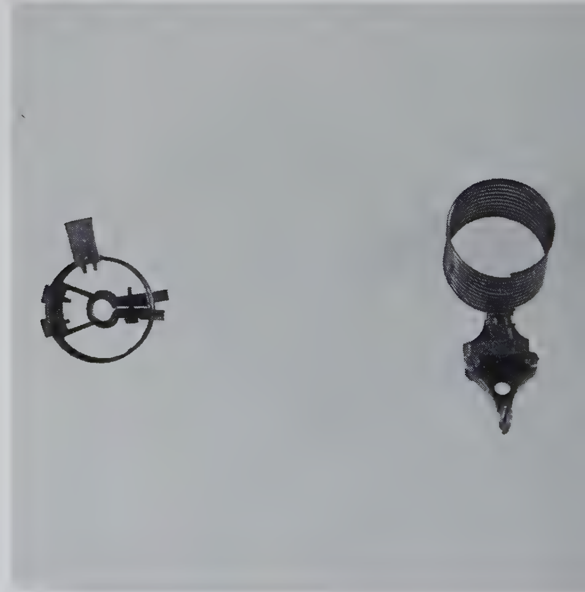

c


d


e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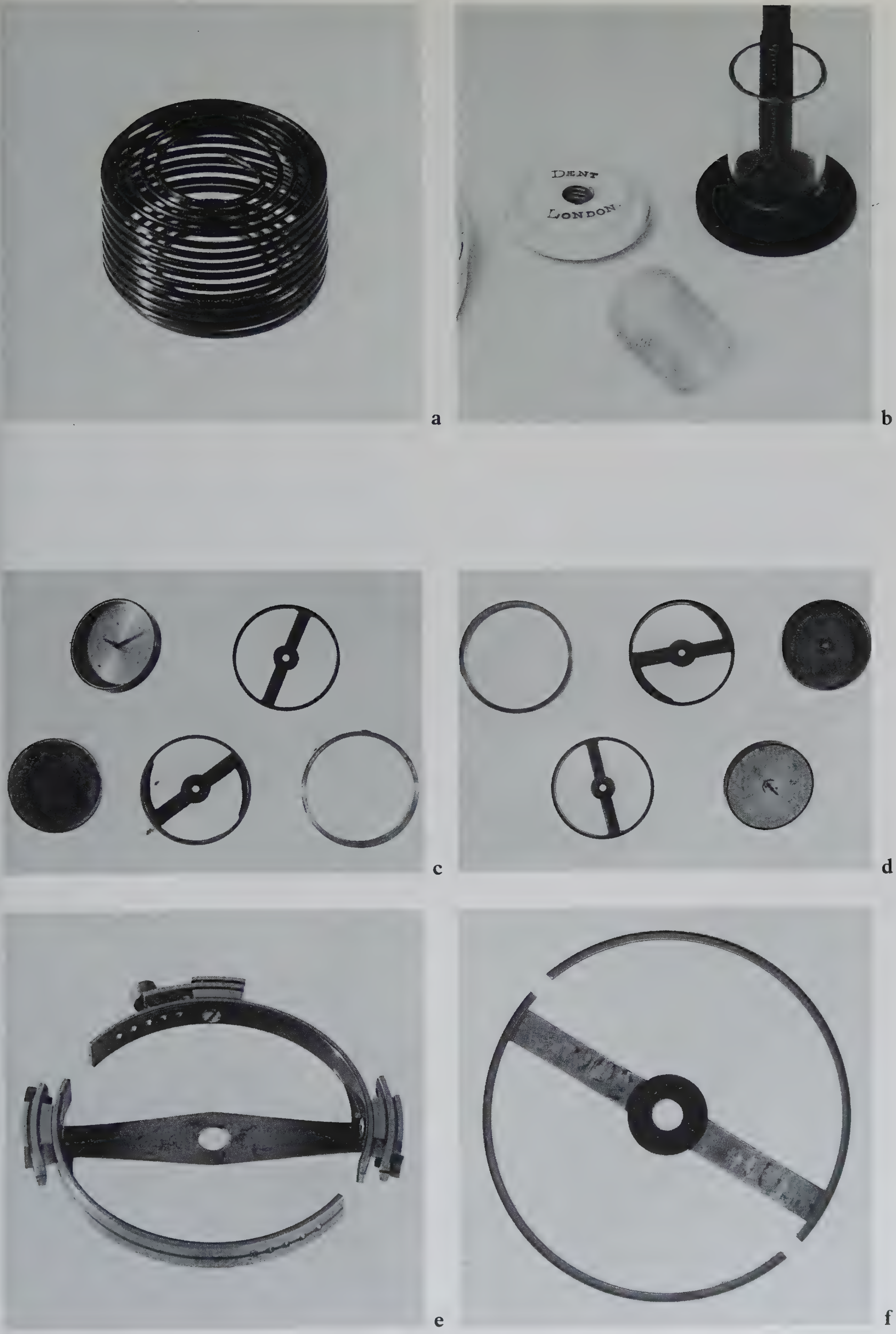
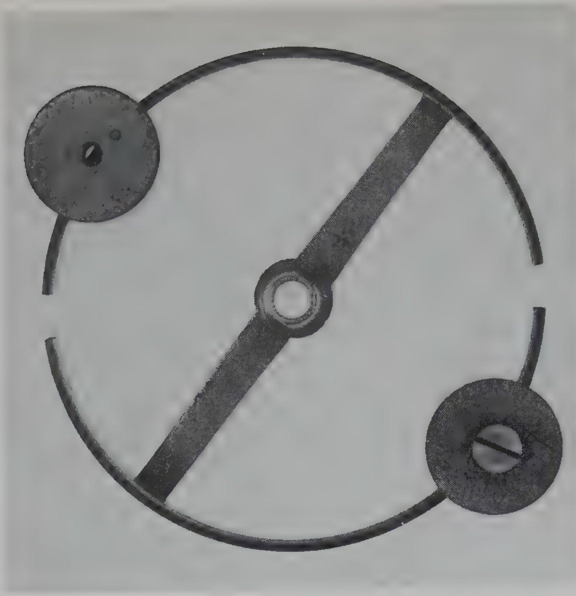

DENT
LONDON
a
b
c
d
e
f

Plate 171

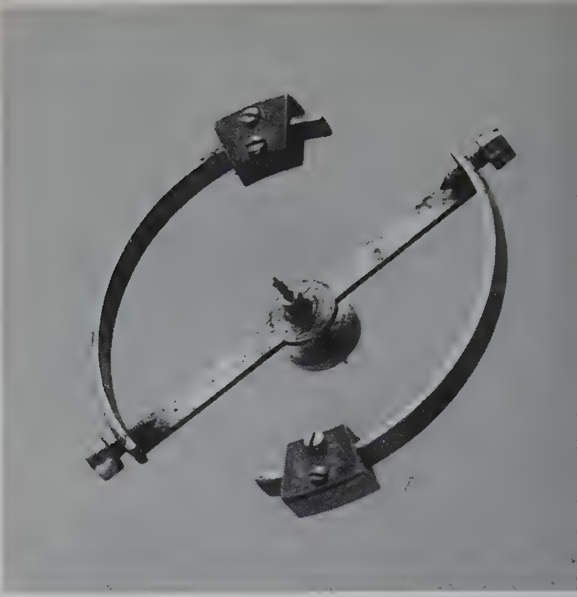
a. Cat. no. 301.
b. Cat. no. 302.
c. Cat. nos. (clockwise, from top left) 315, 314, 312, 313, 315A.
d. Cat. nos. (clockwise, from top left) 312, 313, 315, 315A, 314.
e. Cat. no. 309.
f. Cat. no. 320.

Plate 172

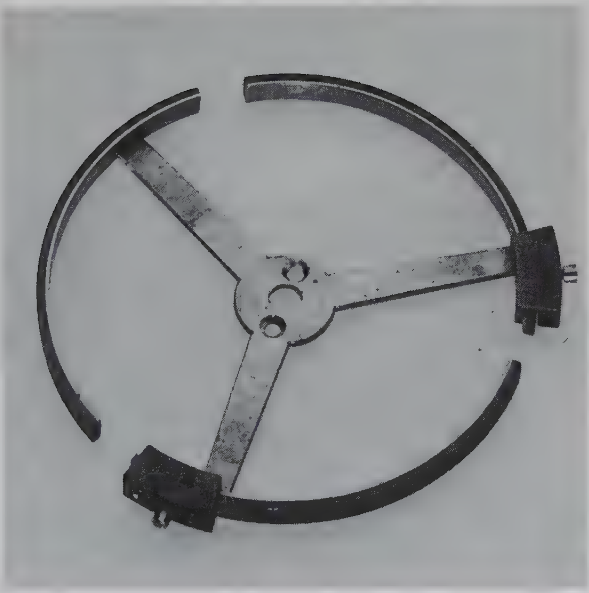
a. Cat. no. 321.
b. Cat. no. 322.
c. Cat. no. 323.
d. Cat. no. 325.
e. Cat. no. 326.
f. Cat. no. 327.



a



b



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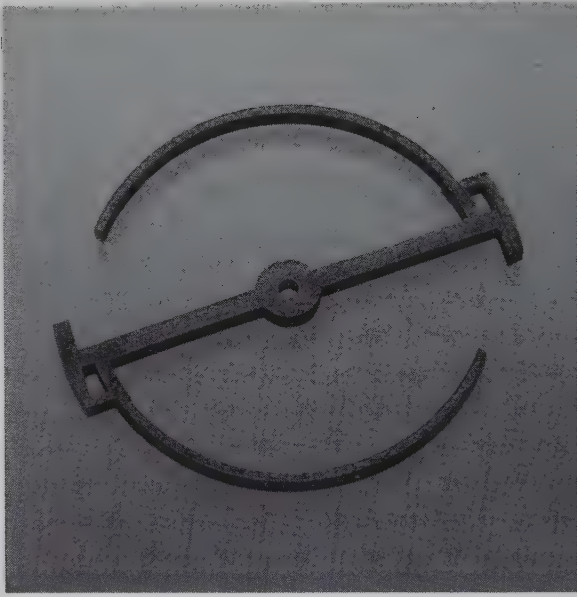

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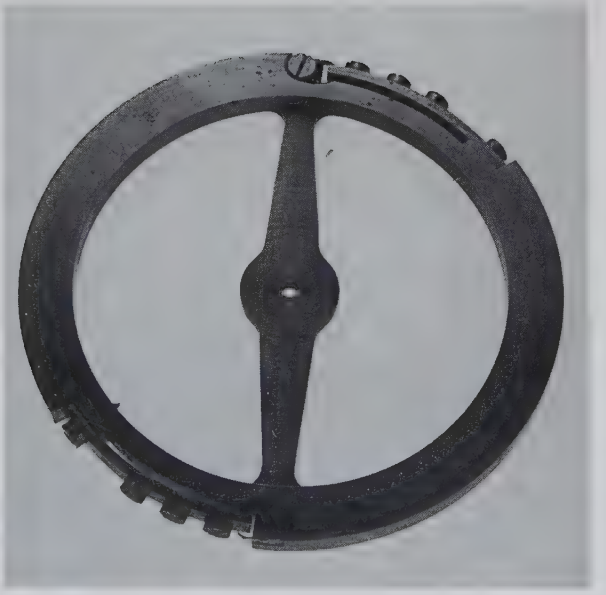
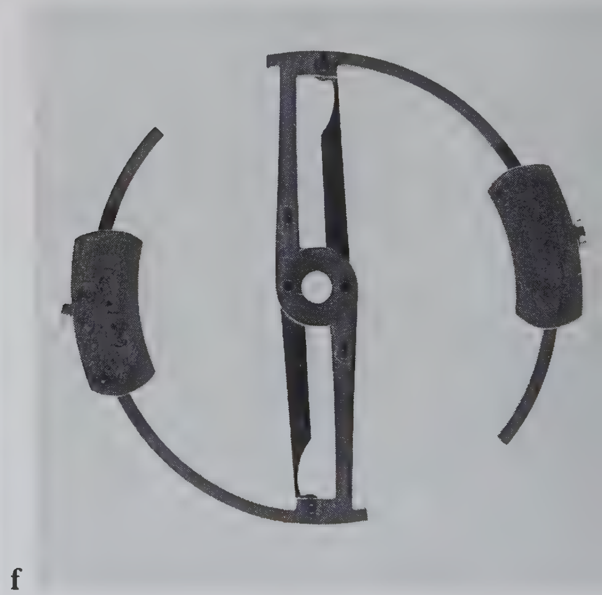


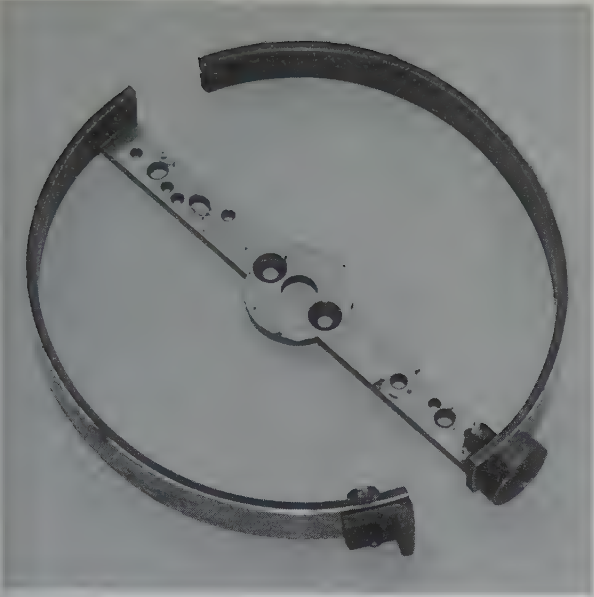
e

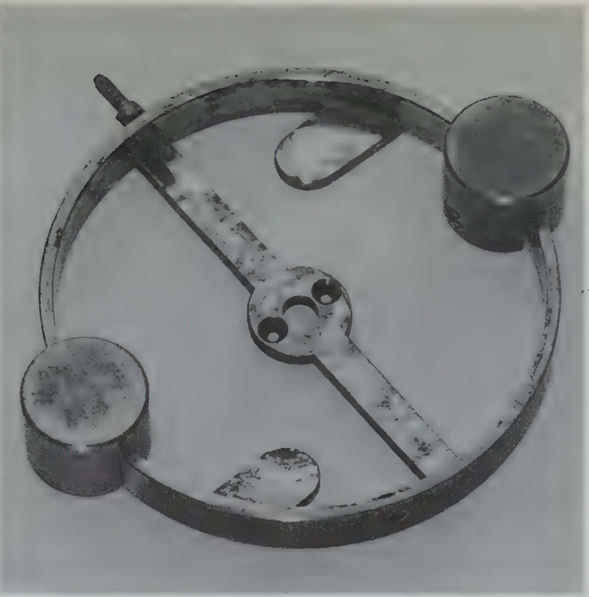


f

Plate 173

a. Cat. no. 328.
b. Cat. no. 329.
c. Cat. no. 332.
d. Cat. no. 333.
e. Cat. no. 334.
f. Cat. no. 335.


a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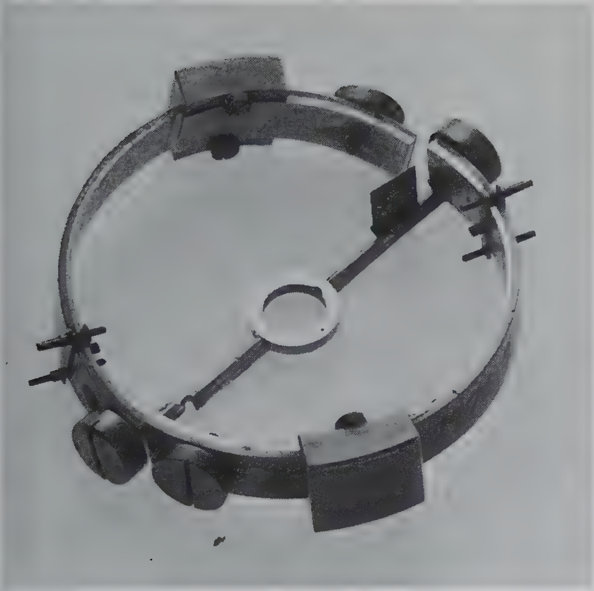
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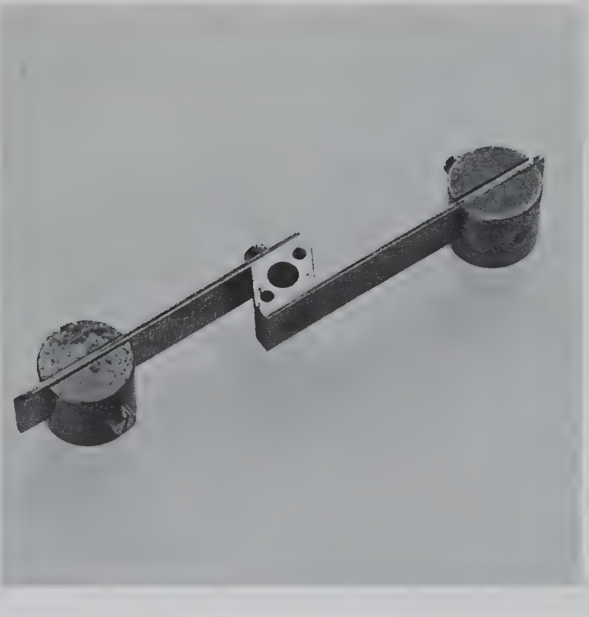
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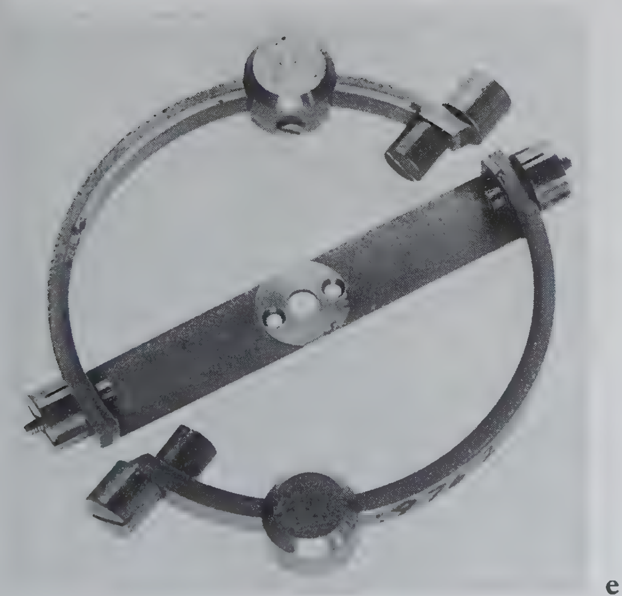
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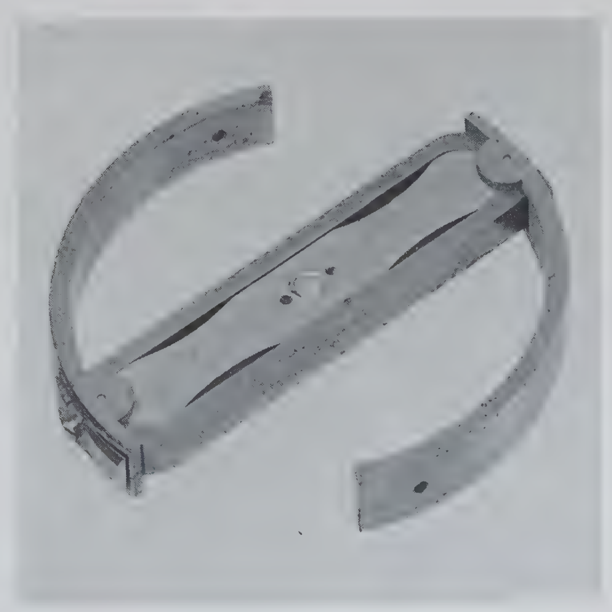
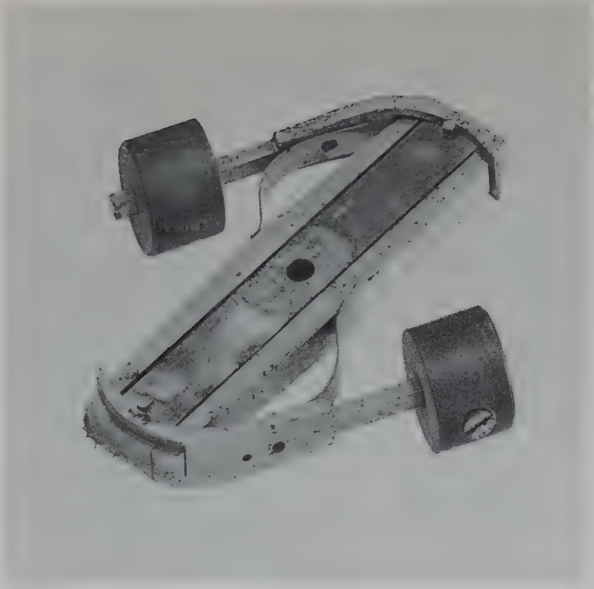

f

Plate 174

a. Cat. no. 336.
b. Cat. no. 337.
c. Cat. no. 338.
d. Cat. no. 340.
e. Cat. nos. (clockwise, from top left) 222, 375, 339, 376, 339A, 222.



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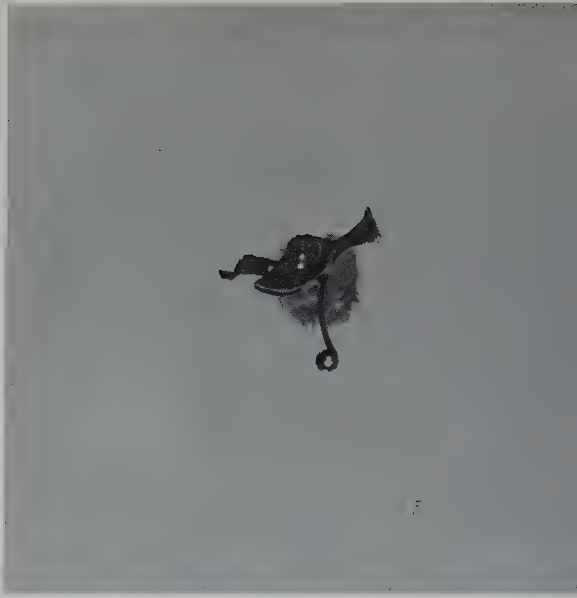

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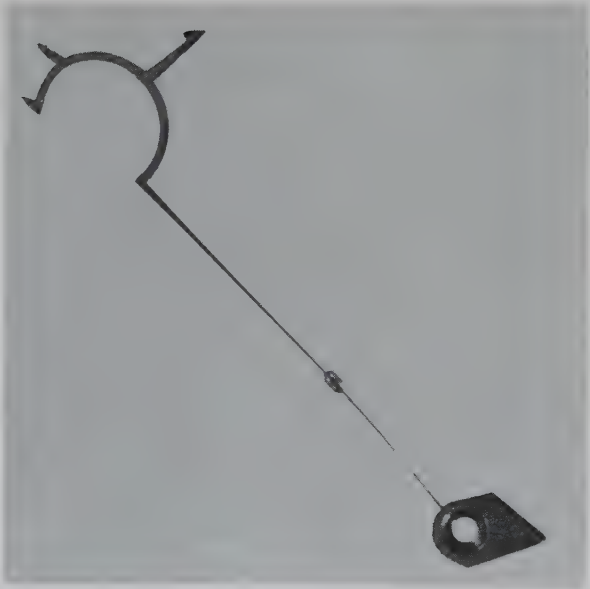

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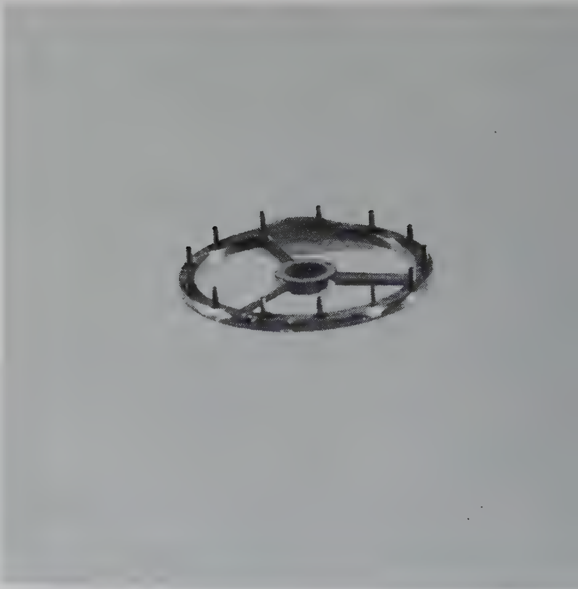

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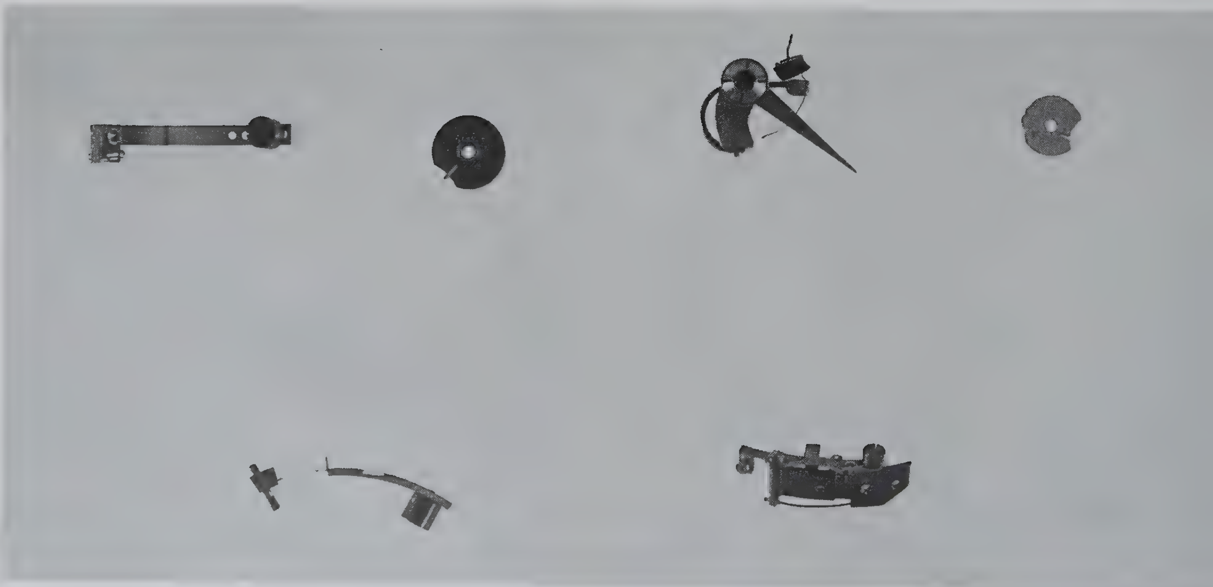
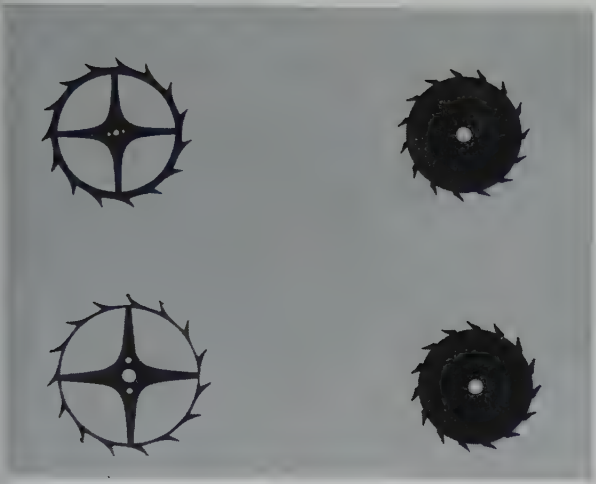


e

Plate 175

a. Cat. nos. (clockwise, from top left) 344, 341, 342, 343.
b. Cat. no. 349.
c. Cat. no. 350.
d. Cat. no. 351.
e. Cat. nos. 352, 353, 354.
f. Cat. nos. (left to right) 277, 355, 278.



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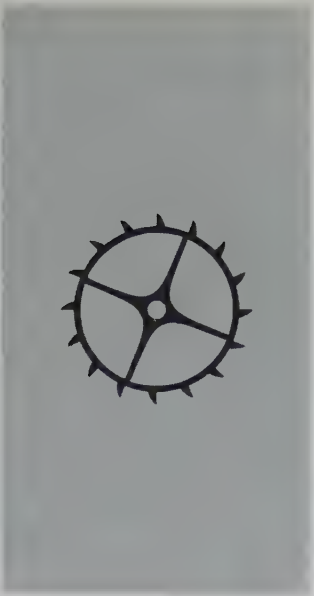

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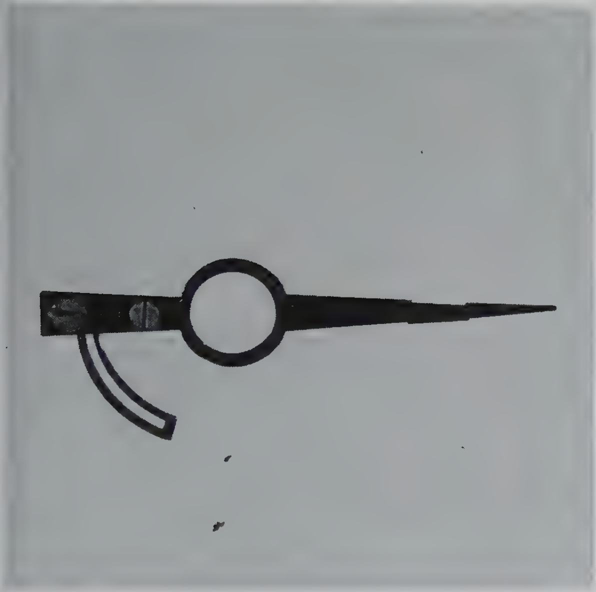

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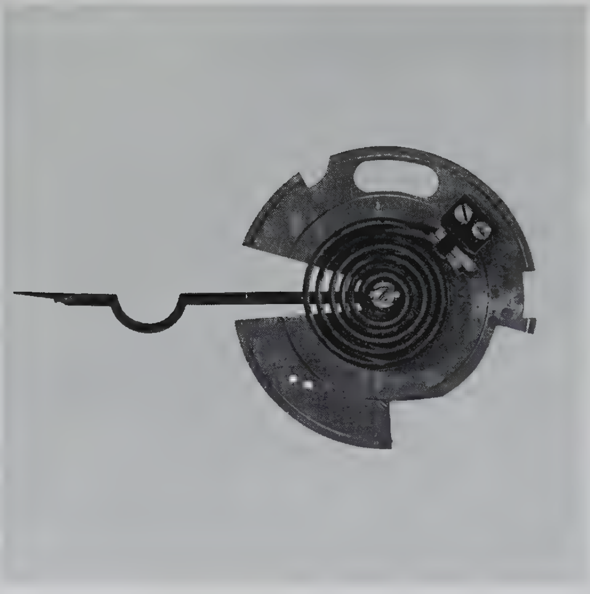

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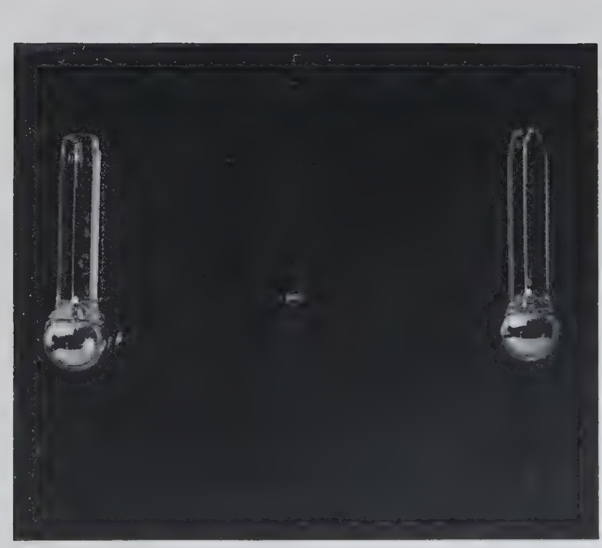
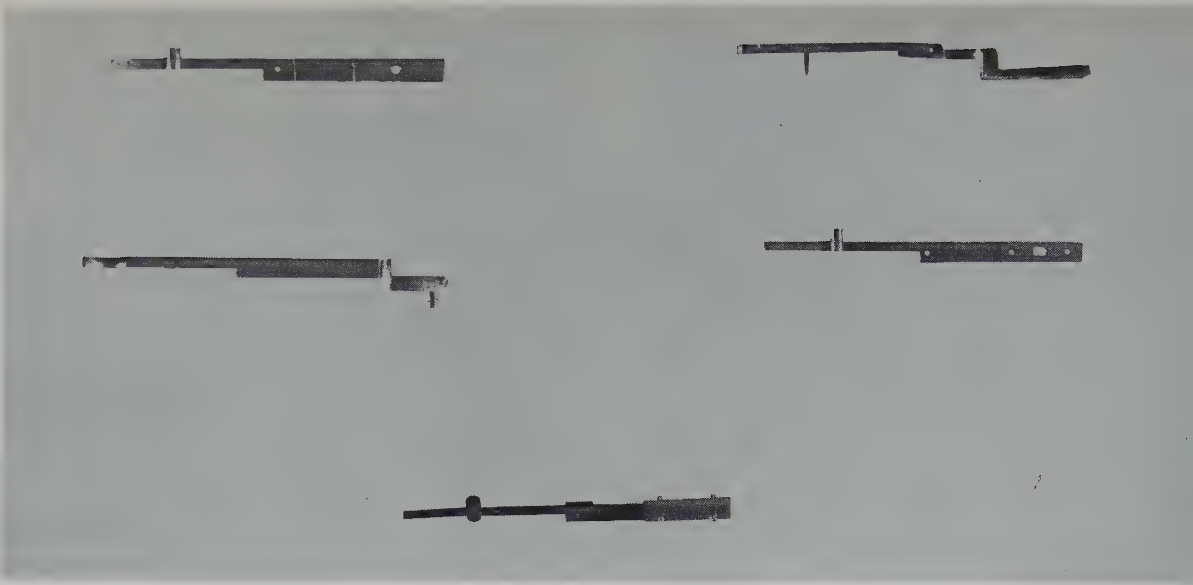


f

Plate 176

a. Cat. nos. (clockwise, from top left) 360, 361, 362, 366, 363.
b. Cat. nos. as above.
c. Cat. nos. 364, 365.
d. Cat. no. 368.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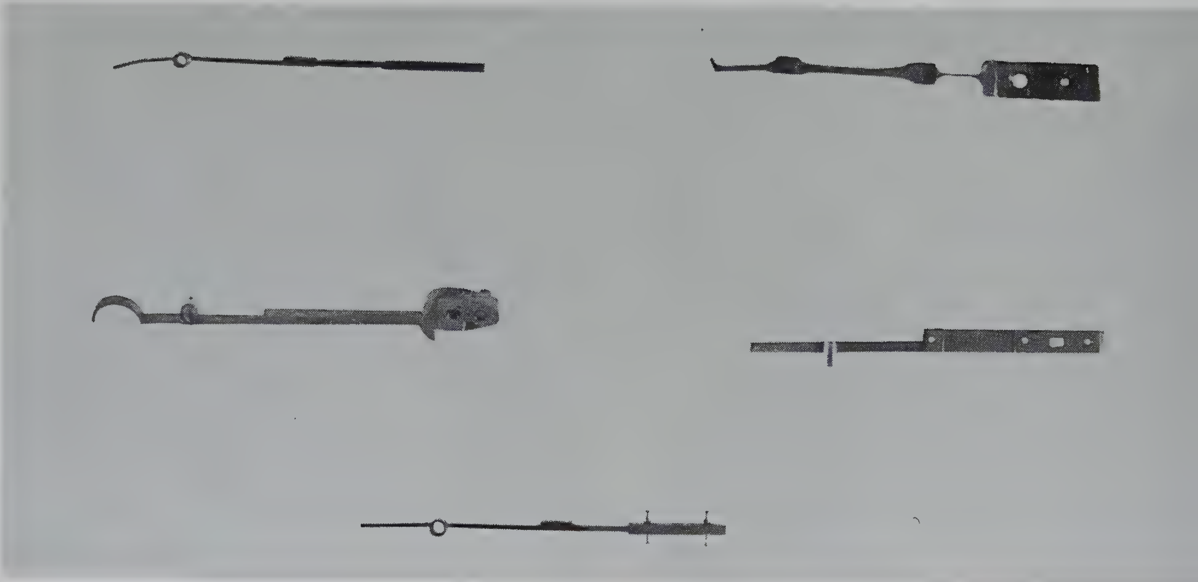
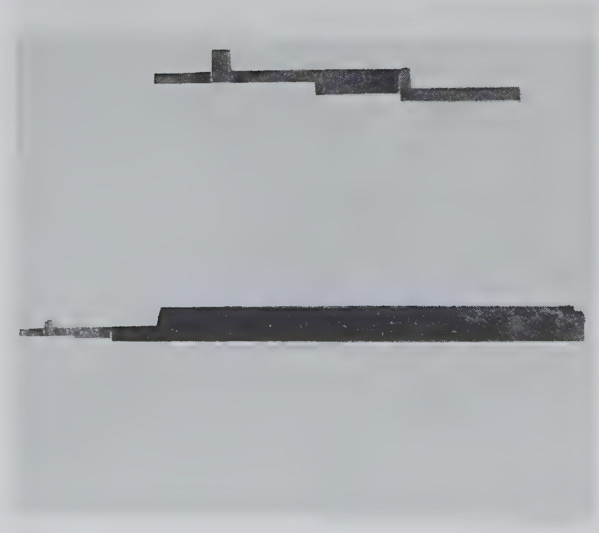

b


c

d

The British Museum's collection of watches was initially formed in the nineteenth century as a result of two outstanding donations, the Lady Fellows Bequest in 1874 and the Octavius Morgan Bequest in 1888. Although this nucleus was supplemented by gifts and purchases over the years, it was not until 1958 that the collection was transformed by the acquisition of the Ilbert Collection. This was saved for the nation chiefly through the generosity of Mr Gilbert Edgar, CBE, and the Worshipful Company of Clockmakers.

Anthony G. Randall was originally trained as a physicist and worked on scientific instruments. In 1963, having been awarded a Fellowship by the British Horological Institute, he went to Switzerland to study horology at the Technicum of La Chaux-de-Fonds. Since then he has worked with George Daniels and taught horology at Birmingham Polytechnic, and is currently engaged in restoration, design and historical and technical research. He contributes regularly to horological periodicals and is author of the forthcoming *Catalogue of Chronometers* of the Time Museum, Rockford, U.S.A. In 1983 he was awarded the Kullberg Medal by the Stockholm Watchmakers' Guild, and in 1985 the Certificate of Excellence and Prize of the Worshipful Company of Clockmakers of London.

Richard Good of the Department of Medieval and Later Antiquities at the British Museum is a Fellow of the British Horological Institute and a Liveryman of the Worshipful Company of Clockmakers. In 1951 he was awarded an Honours Diploma at the National College of Horology, where, as part of his studies, he made the precision watch that inspired his interest in this particular branch of horology. He spent many years in the clockmaking industry, at one time heading the firm of Thomas Mercer Ltd, and eventually joined the British Museum to concentrate on the antiquarian aspects of horology. He was editor of the sixteenth edition of *Britten's Watch and Clock Maker's Handbook* (London, 1978), the 'bible' of the man at the bench. His other publications include *Watches in Colour* (Poole, 1978), *Clocks: An Owner's Handbook* (London, 1985), and numerous articles.

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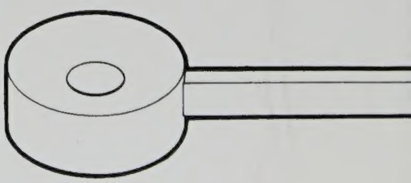

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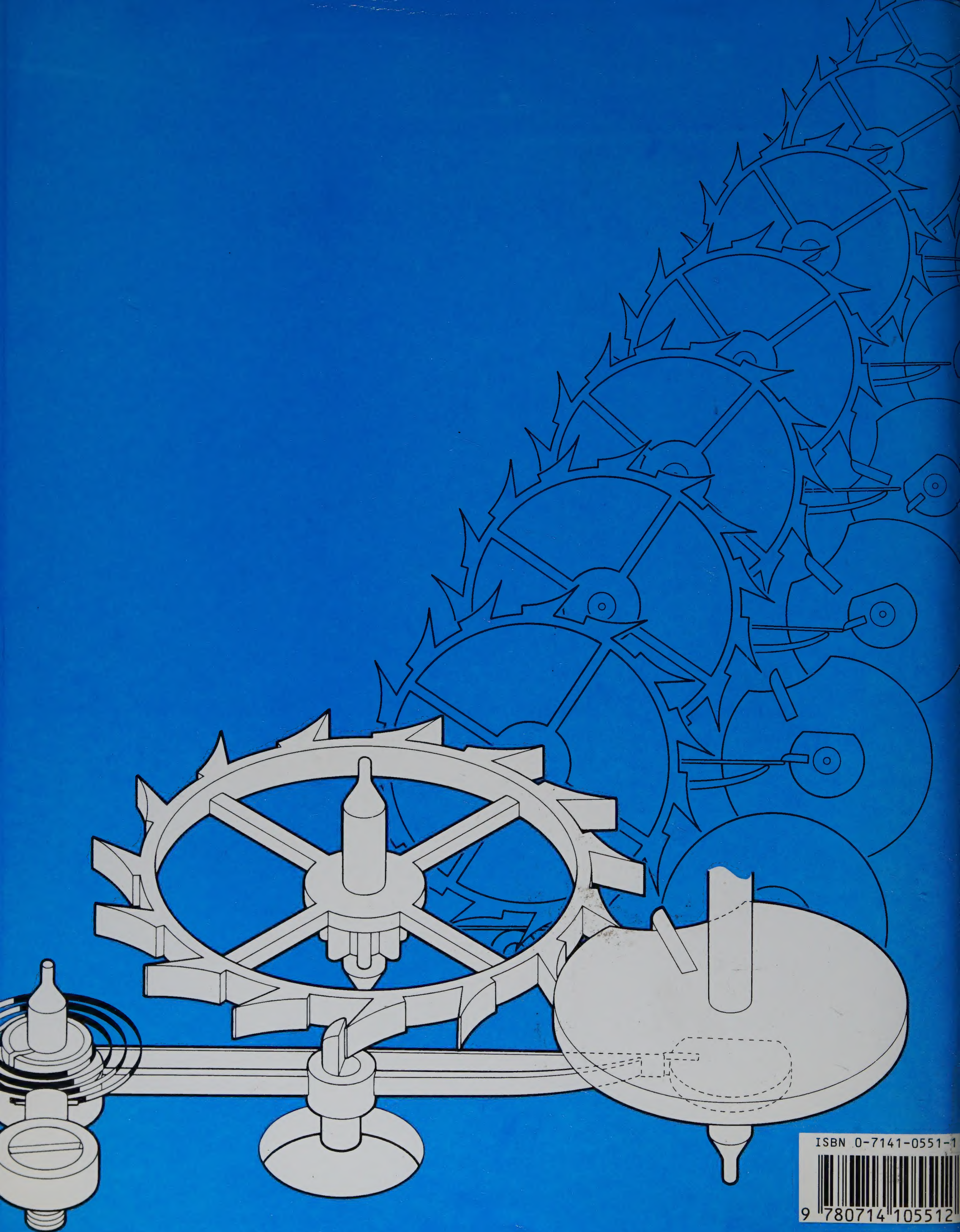

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